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PATTERN RECOGNITION - BODY ARMOUR AND AIRCREW EQUIPMENT ASSEMBLIES - CURRENT SPACE MEDICAL PROBLEMS - AEROMEDICAL EVACUATION

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AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

Pattern Recognition

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Body Armour and Aircrew Equipment Assemblies

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Current Space Medical Problems

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Aeromedical Evacuation

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OCTOBER 1968

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NORTH ATLANTIC TREATY ORGANIZATION

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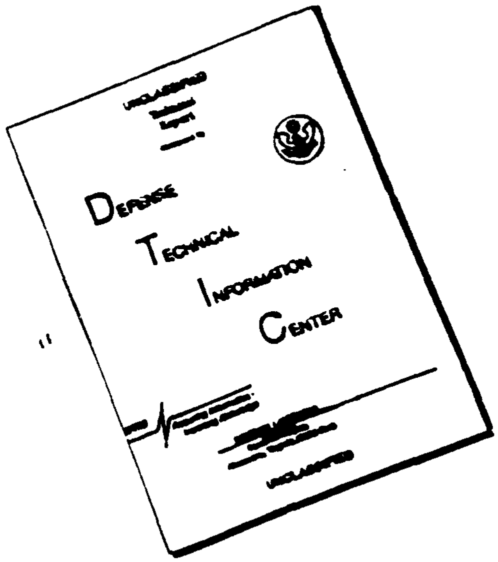

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AGARD Conference Proceedings No. 41

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

PATTERN RECOGNITION

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BODY ARMOUR AND AIRCREW EQUIPMENT ASSEMBLIES

★

CURRENT SPACE MEDICAL PROBLEMS

★

AEROMEDICAL EVACUATION

Proceedings of the 25th Meeting of the Aerospace Medical Panel of AGARD, held in London, England, 15-17 October, 1968.

SUMMARY

This volume contains the text of 29 papers presented at the 25th Meeting of the Aerospace Medical Panel of AGARD, which was held at the Meeting Rooms of the Zoological Society of London from the 15th - 17th October 1968.

The 86 delegates represented 12 NATO nations and the NATO Headquarters, and consisted of clinicians, physiologists, psychologists and engineers; many of these delegates were serving officers of NATO countries, whilst others represented Universities, Industry and Government Establishments. An attendance list showing the current address of delegates is included for the convenience of the reader. The papers are grouped under the four subject headings covered in the programme, namely, pattern recognition, body armour and aircrew equipment assemblies, current space medical problems and aeromedical evacuation. In addition, there is a technical summary which includes information derived from the discussions.

RESUME

Le présent document comprend les textes des 29 communications présentées à l'occasion de la 25ème Réunion de la Commission de la Médecine Aérospatiale de l'AGARD tenue dans les Salles de Conférence de la Société Zoologique de Londres du 15 au 17 octobre 1968.

Parmi les 86 délégues venant de 12 pays membres de l'OTAN et du siège de cette organisation se trouvaient des cliniciens, des physiologues, des psychologues et des ingénieurs. Un grand nombre de ces délégués appartenaient aux forces armées de pays membres de l'OTAN; d'autres représentaient des centres universitaires, industriels ou gouvernementaux. Pour plus de commodité le document comporte la liste des participants, avec leur adresse actuelle. Les communications se groupent suivant les mêmes rubriques que celles des quatre matières prévues au programme, à savoir, la reconnaissance des modèles, les ensembles de vêtements de protection et de matériels pour les équipages d'avion, les problèmes rencontrés actuellement dans le domaine de la médecine spatiale et l'évacuation aéromédicale. On trouvera en outre un résumé technique qui comporte des informations recueillies au cours des discussions.

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PREFACE

The programme at the 25th Meeting of the Aerospace Medical Panel of AGARD covered four main topics, namely, pattern recognition, body armour and aircrew equipment assemblies, current space medical problems and finally, aeromedical evacuation.

This varied programme provoked considerable discussion on many aspects of current aerospace medicine. It has not been possible to provide a verbatim account of these discussions, but the salient features have been included in the technical summary along with the valuable comments of Session Chairmen.

I would like to express a personal word of thanks and appreciation to all the authors for their excellent papers, the Session Chairmen for the benefit of their help and experience, the delegates for their presence and stimulating discussion, and all those whose willing help contributed to the successful outcome of the conference and the publication of these proceedings.

T. G. DOBIE,
Group Captain, RAF,
PROGRAMME DEPUTY CHAIRMAN,
25TH MEETING ASMP

FOREWORD BY THE CHAIRMAN OF THE AEROSPACE MEDICAL PANEL

The 25th Meeting of the Aerospace Medical Panel covered several areas of great operational, military and medical interest and in particular, four main topics:

(a) Pattern Recognition

The first part of this session was devoted to experimental data on a visual theory in target acquisition with special emphasis on search conditions in particular as a function of target sizes, number and duration of fixations and training. The discussion of visual perception phenomena during acceleration brought new aspects into the discussion. After a fundamental neurophysiological presentation on retinal organisation and pattern recognition, the meeting turned to practical implications in discussing the discrepancies and weaknesses of current and future maps and charts in particular with regard to special missions and to illumination. The session was closed by an interesting demonstration of a very promising air-to-ground communication concept.

(b) Body Armour and Aircrew Equipment Assemblies

This session began with a series of presentations on body armour in cooperation with the Structures and Materials Panel of AGARD. The value of body armour in increasing combat effectiveness as a result of user confidence in the armour and higher morale is an important justification for the provision of body armour, quite apart from the overall saving of life and reduction of injuries.

The second part of the session dealt with interesting developments of other aircrew protective devices such as improved aircrew safety harness; a review of a concept of a water-cooled suit; a very interesting photochromic flashblindness goggle; and an evaluation of several modern anti-exposure suits. This session may be considered as an especially good example of joint Panel activities and of AGARD's input to assist in the solution of special operational problems.

(c) Current Space Medical Problems

This session began with presentations describing recent studies on the cardio-vascular and metabolic aspects of hypodynamics, carefully elaborated and evaluated, during prolonged bed-rest experiments. It then continued with an interesting proposal for a cardio-respiratory index derived from mixed venous blood gas tensions. A study of the action of a high-magnetic field on bacterial growth, was then presented as an addition to the circulated programme. The session ended with papers on the problem of oxygen toxicity and fire prevention and protection in oxygen enriched atmospheres; both very important items in current experimental laboratory work and in air and space operations.

(d) Aeromedical Evacuation

This session covered the use of different aircraft types, their missions, and problems of tactical and strategic aeromedical evacuation; the organisation of ground support; trends in peacetime utilisation, especially of helicopters; and the selection policy for early air evacuation, with regard to speciality centres. The session also dealt with system modernisation for the improvement of patients' safety, comfort, care and convenience. An AGARD proposal was realised with regard to a light-weight plastic patient litter. Other new equipment developments were also presented and demonstrated.

In conclusion, I should like to state that the four main topics of the 25th Meeting of our Panel have been well selected, well studied and covered thoroughly. They represent a sound mixture of basic research and operational application. The papers and discussions also provided useful guidelines for future work. I hope that the output will help our NATO Air Forces in the solution of operational problems in line with the mission of AGARD.

E. A. LAUSCHNER,
Professor Dr. med.,
Brigadier General, GAF, MC
CHAIRMAN,
AEROSPACE MEDICAL PANEL.

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SECTION A – PATTERN RECOGNITION

OPENING ADDRESS

BY

PROFESSOR DR. E. A. LAUSCHNER, BRIGADIER GENERAL, GAF, MC

CHAIRMAN AEROSPACE MEDICAL PANEL OF AGARD

"Air Chief Marshal Sir John Grandy,
Other Distinguished Guests,
Panel Members,
Lady and Gentlemen,

It is a great pleasure and honour for me to open the 25th Meeting of the Aerospace Medical Panel of AGARD. I welcome you all, and in particular Air Chief Marshal Sir John Grandy, Chief of the Air Staff; Mr Philip Hufton, United Kingdom National Delegate to AGARD; Air Marshal Sir George Gunn, Director General of Medical Services of the Royal Air Force; and Mr Franklin Ross, Director of AGARD.

I am most grateful to our distinguished guests who have generously consented to address the meeting. It is a particular pleasure for us to have the Chief of the British Air Staff with us today. He is, of course, a particularly busy person and I look upon it not only as a great honour that he has taken the time to be with us, but I hope a significant indication of the close cooperation between our Panel and the operational Commanders. May I therefore introduce to you Air Chief Marshal Sir John Grandy, Chief of the Air Staff, as our first speaker."

ADDRESS OF WELCOME

BY

AIR CHIEF MARSHAL SIR JOHN GRANDY, CHIEF OF THE AIR STAFF

"Mr Chairman,
Lady and Gentlemen,

Firstly, on behalf of the Royal Air Force, I would very much like to welcome our visitors to this country. I hope that you have an enjoyable time with us as well as a productive and useful one. Secondly, Mr Chairman, I would like to thank you very much for doing me the honour of asking me to address this 25th meeting of the Aerospace Medical Panel of AGARD. This is a NATO body and it is very obvious that NATO is daily becoming of increasing importance at this time. Perhaps a year or so ago there was a lot of talk about NATO falling apart and there have been tensions, not tremendous, but certainly tensions within NATO. Recent events however have had I believe a bearing on that and those who have always believed in the significant importance of NATO, like no doubt the majority of you in this room, have only had their views strengthened in recent times. The cohesion of NATO is important and I believe that learned bodies such as yours and meetings such as this make a very large contribution towards this. Apart from all the direct specialist advantages to defence, the exchange of views which takes place and the understanding which builds up between yourselves, also help to strengthen the sinews of confidence and that I regard as vital.

I see from your programme that you are rightly concentrating on man in your deliberations. Man is, if you like, the best computer yet invented in this age of computers. Defence equipment becomes more and more expensive, hideously expensive and therefore it is becoming more and more important that we devise means of exploiting this expensive equipment to the full. The aspects of your work which are directed towards man and helping to make decision-making easier provide a vital contribution to defence.

Looking back to the early days of aviation medicine when all this started, most of us on the flying side rather resented this intrusion by the doctors. We could not understand why these doctors did not remain in the sick wards where they belonged! What were they doing, we asked ourselves, coming to join us in flying? It was not very long, however before we began to understand and appreciate the tremendous things that you could do to help our lives and our existence in the air. I would now like to make two short references to current aerospace medicine. Yesterday morning I saw a film taken of an aircraft accident which occurred earlier this year. The pilot had a run-away tail trim and as soon as he rotated the aeroplane and got the right take-off speed

the aircraft continued to increase its attitude toward the vertical at about 50 feet from the ground. At this point both occupants ejected in their Martin Baker seats, landed quite happily and walk away smiling. The point that I wish to make is that not only was this the result of excellent seat design but also aviation medicine had made its contribution. All the work that the doctors have done on the associated aeromedical problems such as G and so forth, breathes confidence into the aviator. In the flight that I have described which lasted some $12\frac{1}{2}$ seconds from beginning to end the captain had probably only some 3 seconds to decide to eject. The crew had however the confidence that this was going to save their lives. Secondly, this very day, Commander Schirra and his two colleagues are orbiting the globe; what better example of what aerospace means. I can't however resist making the observation and despite having 600 pills with them, Schirra still got a headcold!

Gentlemen, let me conclude by wishing you well in your deliberations. I hope that you will have a fruitful, enjoyable and rewarding 25th meeting of the Aerospace Medical Panel."

The Chairman then continued:

"It is now my pleasure to introduce Mr Philip Hufton, who is a United Kingdom National Delegate to AGARD. He is speaking in place of his fellow National Delegate, Mr Handel Davies, whose kind invitation to the Panel permitted us to hold this 25th meeting in London. This rearrangement of Mr Hufton's appointments in order to join us had to be made at the last moment, quite unavoidably, and we are therefore so much indebted to him that he has made this effort to be with us."

ADDRESS BY MR PHILIP HUFTON
UNITED KINGDOM NATIONAL DELEGATE TO AGARD

"Mr Chairman,
Lady and Gentlemen,

I hope that you will find me an acceptable substitute for Mr Handel Davies, who, as you probably are all aware has been called away at short notice on the important matter of international cooperation on aircraft design and it really does give me very great pleasure indeed to stand in for him on this occasion and to welcome you to the 25th meeting of the Aerospace Medical Panel. AGARD has an important place in the NATO alliance both in giving advice and in bringing together the scientific members of the NATO community and of these the Aerospace Medical Panel really has a very active and significant part to play.

It may seem paradoxical that, despite the increase and development of electronic and a 'onic systems aimed at improving crews skills, it is still and increasingly important to obtain a really good match between the man and the machine. Improved biological definition of flight skills, and matching the environment to the capabilities of man are very necessary and indeed are growing more necessary every day. The Aerospace Medical Panel, along with other panels of AGARD, is playing a very active role in the multi-disciplinary approach to these problems. As Deputy Director of the Royal Aircraft Establishment, I find that the panels of AGARD and their meetings are becoming somewhat of an embarrassment to me because so many of my staff wish to attend them! I am very glad however to see this because it means that the panels are conducting their business well and obviously producing programmes which are extremely attractive to everybody.

As a member of the AGARD Executive Committee I have noticed that the Aerospace Medical Panel is giving a lot of talented assistance to members in the field and indeed to the whole NATO alliance. The panel members are also giving valuable advice to the various member nations over a wide range of aeromedical problems.

I see that this particular Panel meeting is following the usual commendable pattern of covering a wide variety of subjects; it promises to be an extremely valuable meeting both in terms of current problems and those of future importance.

In conclusion I would like to wish all members and delegates at this meeting an interesting and successful programe. I also hope that your stay in London will be enjoyable."

The Chairman then continued:

"I hope that I may be permitted to add a personal note of welcome to Air Marshal Sir George Gunn, Director General of Medical Services, Royal Air Force, whom I have had the honour to know for many years. We are pleased to see you here today, Sir, and it is my pleasure to introduce you to the meeting."

ADDRESS BY AIR MARSHAL SIR GEORGE GUNN, DIRECTOR-GENERAL OF RAF MEDICAL SERVICES

"Mr Chairman,
Lady and Gentlemen,

It is a very great pleasure indeed for me to associate myself with the Chief of Air Staff and Mr Hufton in welcoming the Aerospace Medical Panel to London, and perhaps I'll be forgiven if I make this very brief personal reference to one or two of my old friends in the audience. Firstly, it is particularly pleasing to meet again Professor Erwin Lauschner. General Lauschner, as he has just told you, I have known for many years and I have listened to him and watched him many times stimulating discussions and promoting the interests of aerospace medicine at all levels and in many countries. I think that you are particularly fortunate to have him now as your Chairman with his keen interest and wide knowledge of aviation medicine, to guide your deliberations.

I had looked forward very much also to seeing General Albrecht the former Surgeon General of the German Armed Forces at this meeting, but I was very sorry to learn this morning that he was involved in a motor accident a few weeks ago and is unable to attend. I hope therefore, Mr Chairman, that you will be good enough to give him our warm regards and wish him the very best for a speedy recovery.

I would like to welcome Professor Mercier of France; it is a great pleasure to see him again and I had also hoped to welcome General Evrard from the Ministry of Defence in Brussels and Karl Houghton who was formally in the US Air Force but is now with the McDonnell Douglas Company; but I do not see either of them in the audience at the moment. I am, however, very glad that they are attending and look forward to seeing them and many other friends this evening.

I don't need to emphasise how pleased I was that the previous speakers talked about the importance of the human factor in the aerospace system, and the importance of having medical doctors in the multi-discipline teams, both for the promotion of research and for the interpretation of the results. I believe that the Aerospace Medical Panel of AGARD has perhaps a unique advantage in having a large proportion of flight surgeons or flight medical officers amongst its members thus providing close association and familiarity with the problems of operational flying.

Your agenda for the next two days shows that there is no lack of interest and effort being put into the aerospace medical field, and I am very happy that our Royal Air Force medical branch is able to support AGARD both at home and abroad. We are particularly happy that you are going to the Institute of Aviation Medicine at Farnborough on Friday and I am sure that you will see much of interest there.

I wish you an interesting meeting and an enjoyable stay."

The Chairman then continued:

"Finally, it is my great pleasure to introduce Mr Franklin J. Ross, the Director of AGARD. I am sure that we are very pleased indeed that the Director has been able to find time to attend our 25th meeting."

ADDRESS BY MR FRANKLIN J. ROSS DIRECTOR OF AGARD

"Mr Chairman,
Lady and Gentlemen,

It is a pleasure for me to welcome you, on behalf of AGARD, to the 25th Meeting of the Aerospace Medical Panol. The topics of the programme indicate very strongly to what extent aviation

medicine is contributing to the operational aspects of NATO's mission.

The programme is well balanced and covers several areas of great operational, military and medical interest. In particular, I should like to point out the successful cooperation with another AGARD Panel, the Structures and Materials Panel, which has contributed to the section on body armour. On several previous occasions, the Aerospace Medical Panel has very successfully sponsored or co-sponsored joint meetings which allow an inter-disciplinary approach to problems.

I am convinced that you will find the presentations as interesting as they appear to me on reading the programme.

May I wish you a successful meeting and a good journey home afterwards."

The Chairman then concluded his remarks:

"I am sure that you will all agree that our guest speakers have been very generous in their remarks concerning our Panel activities, and it is my pleasure to thank them on your behalf.

As Panel Chairman, I wish to record our appreciation to the United Kingdom for their kind invitation to hold this year's Panel meeting in London. We are very happy to be here and it is a personal pleasure to me to see so many old friends in the audience.

As far as our programme is concerned, it will be devoted to four main topics which will be covered in separate sessions.

The first broad topic is "Pattern Recognition", particularly in visual but also in auditory systems, under conditions in which recognition is impaired by reason of low contrast or confusing backgrounds, requiring consideration of the mechanisms of sensory perception. As examples, I would like to mention the problem of air-to-ground reconnaissance and the design of maps and charts best suited to various operational roles.

The second part of our meeting will be dealing with "New Developments in Aircrew Protective Systems, including Body Armour". The Structures and Materials Panel of AGARD has contributed two presentations for this session, demonstrating not only the good cooperation between the AGARD Panels but even more the current interest in this problem area.

"A Review of Current Space Medical Problems" has become a permanent part of our programme, and this year it promises to be of special interest. I am also sure that our best wishes go out to the crew of the Apollo spacecraft in orbit.

Our last topic is "Aeromedical Evacuation of Patients" and will cover current trends in the development of aeromedical evacuation equipment. This session will allow contributions on recent aeromedical, clinical and operational experience, aimed at improving techniques and equipment presently in use in aeromedical evacuation.

In conclusion, I extend my warmest personal greetings to you all, our guest speakers, Panel members and delegates to this meeting. It is my sincere hope that the meeting will not only be interesting, stimulating and useful to the medical branches of NATO, but will also be a contribution to the effectiveness of our operational Air Forces.

Gentlemen, we now have a coffee break. In view of the location of the meeting here at the London Zoo, I am wondering whether we really will get coffee or peanuts!"

VISUAL THEORY IN TARGET ACQUISITION

by

Dr. E. B. DAVIES

Royal Aircraft Establishment, Farnborough.

Summary

The theoretical approach to visual search for a target based on the target's contrast and size and the concept of visual-lobes is reviewed briefly. New flight data for foveal contrast size thresholds, related to the maximum detection ranges of prominent terrain objects, are found to compare favourably with laboratory data from much simpler visual tasks.

Two laboratory search experiments analysed in terms of visual theory are shown to agree well with it, with little modification of the data used in the theory from certain selected but otherwise standard data. In particular, glimpse times of the order $\frac{1}{3}$ to $\frac{2}{3}$ seconds are found to be quite adequate to describe the experimental results.

A PART OF the work of the Royal Aircraft Establishment is the task of assessing the performance of aircraft pilots and navigators in finding ground targets, both using unaided vision through the cockpit canopy or optical or electro optical systems such as television. The visual targets on the ground may be anything from terrain features which are useful for navigation to targets of military significance, and the answers required are used in an equally large variety of ways from detailed project specification of present systems to broad assessment studies of future systems. For example, a problem very much in vogue at present is that of defining the best height and speed for future ground attack aircraft, a problem which is an extremely complicated mix of aircraft effectiveness in the tasks set and the defense effectiveness.

Much of our effort goes into a flying programme as this tends to give the most reliable answers, and is frequently the quickest. But, we also put a lot of effort into simulation and, as a broad link to all the facets of our work, as well as prediction in its own right, visual theory. It is this last aspect of our work, the use of visual theory in the prediction of the detection ranges of targets in search situations that is presented in this paper. This theory is not new, but there is a marked lack of any corroboration of the theory by testing it against actual visual performance. The two tests included here and the flight data on visual thresholds achieved in the absence of search in an air-to-ground target detection task are, consequently, of great interest.

In the following sections, the visual theory is first introduced very briefly, with the flight measurements of visual thresholds, and then the analysis in terms of visual theory of two laboratory search experiments is presented.

VISUAL THEORY

The visual theory I am going to talk about today may be considered in two parts; first, visual performance when no search is involved; and second, the way this is modified by search. The first part concerns the visual limitations of the fovea, the part of the retina used when looking directly at something, and the second part is concerned with the increasingly poor resolving capabilities, (under normal 'daylight' lighting conditions at least), of retinal regions further from the fovea. These two aspects are considered separately in the following two sub-sections.

FOVEAL VISION : The concept used in the theory is the very familiar one of considering visual detection to be limited by the contrast and size of a target. That is, if a target has a certain contrast with its background, an observer will only see it if he moves close enough that the target subtends a certain threshold size at his eye. This is illustrated in Fig.1 which depicts a typical curve derived in laboratory experiments to relate the contrasts and sizes of targets which are 'just' visible to an observer. [In fact, the dividing line between targets being visible or invisible is not a sharp one, and the actual lines depicted usually correspond to the contrasts and sizes of targets which are seen by the observers on 50% of presentations, viz, the line for 50% frequency of seeing. A rough and ready rule for converting these 50% thresholds to higher frequencies of seeing is that, in the laboratory at least, nearly double the contrast is required to allow for an increase in the frequency of seeing to 95%. There are, of course, also differences between observers corresponding to factors of two on the threshold target contrast.] Given a curve such as in Fig.1, and the atmospheric visibility, it is relatively easy to predict the mean value and the variability of the detection range of a simple disc target specified in terms of size and its contrast relative to a plain background.[2,3,4,5,6] However, what does not appear to have been appreciated is that there is no single threshold curve as in Fig.1, but that even in the ideal conditions of the laboratory tremendous differences between threshold curves are obtained depending on the precise conditions of the experiment. This is illustrated in Fig.2 where a variety of such curves [7,8,9,10] have been collected; the spread of these curves is seen to be extremely large and such that targets which would be predicted to have been seen at very long range by the more optimistic data are not seen at all according to other data.

One of the disturbing features of the curves in Fig.2 is that not all the curves may be converted into other threshold curves by simple translation along the contrast axis. This implies that the standard technique of correcting laboratory data to practical circumstances, by multiplying the laboratory contrast thresholds by a constant degradation factor, is unlikely to be valid for all target sizes unless one first starts with a laboratory curve of the right shape. This 'right shape' can really only be defined for a given viewing situation by comparison with measurements for that situation, but for aerial observation some of the circumstances of the laboratory experiments, such as the unlimited exposure time of one of Blackwell's curves, would also suggest their inapplicability to most real viewing situations. The visual lobe equation would also seem to be at variance with the rest of the data by the way that it is so steep for the larger target sizes.

In reference 11, some data are available for contrast/size thresholds of ground targets, such as large country houses, large bridges and etc., when viewed from the air. In this air trial, the detection ranges for the targets were measured at the same time as the approaches to the targets were being filmed, and the films were then analysed for the apparent contrast and size of the target at the flight detection range. These data are compared with the laboratory data in Fig.3, where it is seen that the points are scattered about a shallow curve within the spread of the more pessimistic laboratory data. This is quite surprising as all the laboratory

data is for uniform disc targets in plain backgrounds so that the flight situation would appear to have introduced no degradations due to either the less comfortable viewing environment or the complex backgrounds to the target. This could have been due to the fact that the targets were very prominent in their backgrounds, and we are pursuing this work to extend the data to a wider range of targets.

SEARCH : In most viewing circumstances, visual performance is not as good as indicated by foveal considerations simply because the observer has to search for the target. In this case, the target may first be detected by vision away from the foveal regions; though one would normally immediately turn the fovea on to the target to check the extra-foveal detection.

The analysis of search situations assumes that search proceeds in a series of independent glimpses, each glimpse covering a certain amount of the search area, whether the background be plain or composed of confusable objects. The amount of the search area covered at a single glimpse is commonly called a 'visual-lobe', (not to be confused with the visual-lobe equation which is simply an equation which purports to define the sizes of visual-lobes as a function of target parameters). The visual lobe concept is discussed fully in reference 12; for the present, the hard-shell approximation to the real visual facts are pursued. This approximation is illustrated in Fig.4. In this figure, a single glimpse at a target has around its axis contours of the frequency (probability) with which a target of given contrast and size would be seen if placed on that contour. This frequency of seeing has a maximum value on the axis and reduces to zero at large angular distances from the axis. The hard-shell approximation is seen in Fig.4 to be an area equivalent to an average of the distributed frequency of seeing contours such that inside the shell a target is taken to be seen, and outside it the target is not seen. The assumption is directly equivalent to assuming that the foveal threshold curve in Fig.1 represents a sharp boundary between visible and not visible.

Two sources of data for the performance of the retina in regions away from the fovea have been used to calculate visual lobe sizes, the visual-lobe equation[4] and J. H. Taylor's data[8]. These are compared in Fig.5 where it is seen that while they have much in common, there are also marked differences. Other data reviewed in reference 13 supports the J. H. Taylor data, but in view of the fact that many other experimental results which could be interpreted in terms of visual lobe sizes have appeared in the literature since this review, a further review of extra-foveal visual data would not be inappropriate at the present time. All our latest theoretical work uses the J. H. Taylor data.

Thus, in principle we have the means to predict visual performance in any given search situation. In practice, of course, there are many difficulties; for example, the number of useful, independent, glimpses per second is not well defined for real life viewing; the definition of the search path likely to be taken by the observers cannot be specified in most cases; and, the detection of real targets probably involve deeper intellectual processes than the detection of plain discs in plain backgrounds so that the observer needs a 'thinking time' as well as a search time. However, as a start to testing this theory in search situations, the results of two laboratory search experiments have been analysed in terms of this theory. In both experiments, the observers searched for a small low contrast target in a plain search area, but in the second experiment, the target grew in contrast and size from being initially invisible at the start of search.

ANALYSIS OF EXPERIMENTAL DATA

The first experiment to be analysed was that by Krendel and Wodinsky[14]. The observer searched for a target in a plain background, and the target size and contrast, and the background size and luminance were varied systematically. Under such circumstances, and the assumption of random glimpsing, the proportion of targets seen in time t could be expected to be given by

$$p = 1 - e^{-t/\tau}, \qquad (1)$$

where τ is a time constant for the search situation. Krendel and Wodinsky found that most of their data fitted this equation, with the exceptions of targets which were very near the foveal threshold of vision when extra time seemed to have been needed by the observers to make up their mind as to whether the object they were looking at was really the target. They concluded that visual search in such circumstances was <u>effectively</u> random, even though it is also known that observers do try and be a little more systematic.

In terms of a visual lobe of radius 'θ' degrees in a search area of radius ϕ, and with the assumption of $\theta \ll \phi$, τ is given by

$$\tau = \left(\frac{\phi}{\theta}\right)^2 . T \qquad (2)$$

where T is the average time required to make a glimpse. This equation predicts that τ should increase linearly with the solid angle, ϕ^2, subtended by the search area, and again, with a few exceptions for the near threshold targets, this was found to be true. An example of the data is shown in Fig.6A. In Fig.6B is shown an example of the data for near threshold targets where the straight lines do not go through the origin, possibly because Krendel and Wodinsky's original analyses of the data did not allow for a substantial reaction time in these situations,

or possibly because of other genuine but rather inexplicable+ aspects of such situations. The slopes of these lines allow, from equation 2 with an assumption for T, for the calculation of θ, the radius of the effective visual lobe. Values of T of $1/6$, $\frac{1}{3}$, $\frac{2}{3}$ and $1\frac{1}{2}$ seconds were tried in the analysis, with the resulting variations of θ with target contrast compared with the laboratory data for each target size. The best fit was given by a value for T of $\frac{1}{3}$ sec with J. H. Taylor's data, as depicted in Fig.7; though nearly as good a fit was also given by a glimpse time of $\frac{2}{3}$ second and slightly different foveal thresholds from those used to construct Fig.7. (These foveal thresholds will be discussed later.) It is seen that the experimental search data is quite consistent with laboratory data on the sizes of visual lobes and glimpse times. It must be admitted, however, that because the experimental targets were so near to the foveal threshold the prediction of the experimental search time constants from the ideal data, or even from the smoothed experimentally derived values of θ, results in extremely large random errors.

The second experiment analysed was undertaken at the Royal Radar Establishment[15] at Malvern, England, and was a simulation of an observer searching for an aircraft that was flying directly towards him. The observer looked at a white screen illuminated to 100 ft L, and on this screen was superimposed a diamond shaped target which increased in size and contrast according to the geometrical and atmospheric laws governing the real-life situation. The target size and the visibility were varied as main variables, and some work was also done for different target contrasts and approach speeds. Attempts were made to predict the experimental results with only two manipulations being allowed in the theory, viz, the choice of glimpse time and the foveal thresholds for each target size. A comparison between theory and practice is shown in Fig.8. It is seen that the shapes of the experimental distributions, particularly their slopes at the median ranges, have been predicted extremely well by theory.+ The effect of target size is also well matched by theory, as although the positioning of the graphs along the range axis has been manipulated separately through the degradation constant on the foveal threshold, the range error without such separate manipulation would only have been +0.2 km, and -0.2 km for the small and large target respectively. One of the interesting features of Fig.8 is that it shows so clearly how the manipulation of the maximum possible detection range, the toe of each distribution, seems to move the whole distributions along the range axis with little effect on the shape of the distributions, so that in this particular instance the search and foveal aspects behave independently of each other.

In Fig.9, the theoretical effect of visibility on the detection of the medium sized target is compared with practice. The effect of the 10 km limit to the simulation is apparent in the way that some distributions have been squashed against the higher ranges, but it is seen that theory has reproduced this correctly and is again in good agreement with practice.

The analysis of the Krendel and Wodinsky and the RRE data provided values for the foveal thresholds appropriate to their viewing circumstances and their sample of observers, and it is interesting to see the comparison of these in Fig.10 (from reference 12) with the field data reported earlier. The thresholds derived from the search experiments for the plain targets in the plain backgrounds are seen to agree quite well with the flight data. This is quite surprising in view of the complex backgrounds for the field targets, and reflects the inexplicably small differences found between the flight data and the established laboratory data in section 1.1.

These analyses of the two search experiments above have shown that the experimental data can be described by visual search theory using quite standard visual data in all respects. It is particularly interesting that glimpse times of the order $\frac{1}{3}$ - $\frac{2}{3}$ sec, which agree with laboratory measurements, were found adequate, and that the foveal thresholds agree so well with other laboratory data. The element of dynamics introduced by the second, RRE experiment in the way that the target approached the observer appears to have had no adverse effect on the theory which encourages the use of the theory in such circumstances.

DISCUSSION AND CONCLUSIONS

The analyses of the two search experiments in this paper encourages the use of visual theory in circumstances of search, and the comparison of the field foveal thresholds with laboratory data suggests that this search theory may also apply to real life search circumstances as well as to idealised laboratory search circumstances. However, some internal features of the present analyses, particularly that of the Krendel and Wodinsky data, suggest that field targets rather less prominent than those used in the flight trial may introduce difficulties, and the next phase of our work at the Royal Aircraft Establishment is certainly to attempt to test visual theory with such targets. Flight trials which are suitable for good theoretical analysis are, however, relatively infrequent, and progress must consequently be relatively slow.

+ It must also be mentioned that all the experimental distributions in Figs. 7 and 8 could have been matched almost as well with a glimpse time of $\frac{1}{3}$ sec instead of the $\frac{2}{3}$ sec actually used, but also using slightly (0.1) higher degradation constants on the foveal thresholds. The slopes of the distributions at their median range proved to be relatively insensitive to the assumed glimpse time.

One of the interesting aspects of the analyses of the search experiments is that the experimental results have been matched by the use of relatively standard, albeit selected, data in the theory. In particular, glimpse times of the order of $\frac{1}{3}$ to $\frac{2}{3}$ seconds were found to be adequate, in contrast with the $1\frac{1}{2}$ seconds often considered necessary to apply to 'operational' search. The definition of effective glimpse times for a wide variety of search tasks is obviously an important step in using visual theory and the present values of $\frac{1}{3}$ to $\frac{2}{3}$ seconds need to be tested in more difficult tasks.

In view of the difficulty mentioned above in obtaining good trials data for theoretical analysis, an important step in the further development of the theory must be in laboratory simulation of the real task, not necessarily with scale models of real search situations, but possibly with synthetic tasks which appear to contain all the elements of the real situation, such as the existence of backgrounds or the difficulty of the targets. Paper A.2 in these proceedings by Professor C. I. Howarth and Mr. J. Bloomfield concerns simulation work which has been proceeding on these lines at the University of Nottingham to investigate the application of visual search theory to situations with a non-uniform background.

In conclusion, it may be said that whereas this paper has highlighted the very large variability in visual performance which exists in even the simplest of laboratory target detection tasks, which does not encourage the hope for accurate prediction of inflight performance, the flight detection data and the analyses of the search experiments show that the link between the present visual theory and real life target acquisition is a strong one. There are undoubtedly many obstacles to be overcome before we can expect theory to be the complete predictor of visual performance, but this paper has shown that it is worth making the effort.

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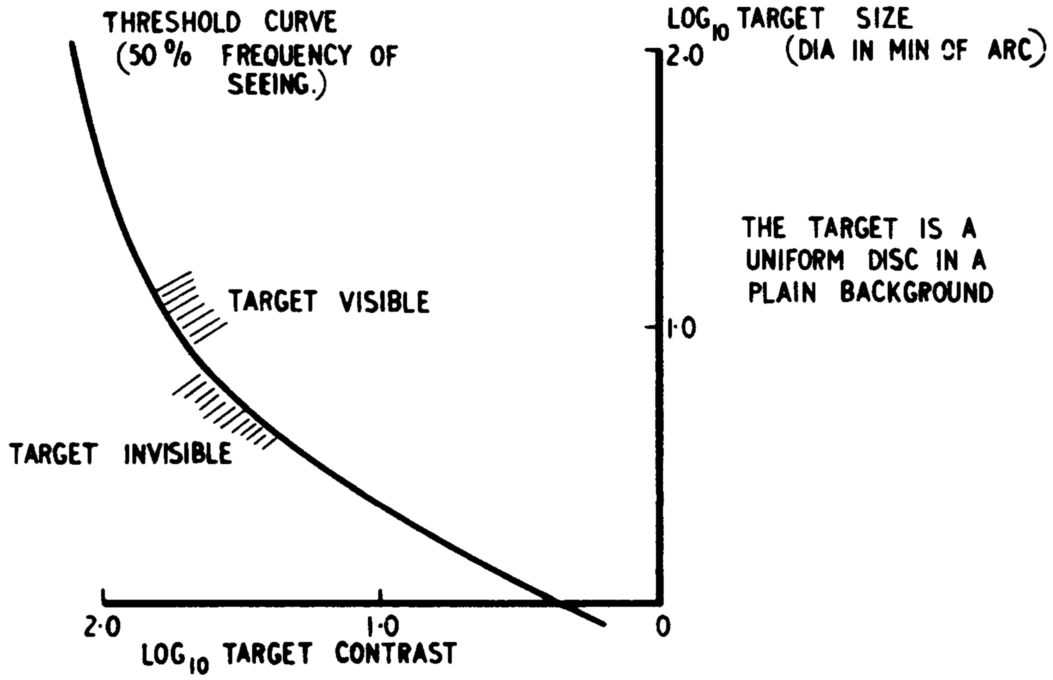

FIG.1 AN EXAMPLE OF A CONTRAST/SIZE FOVEAL THRESHOLD CURVE

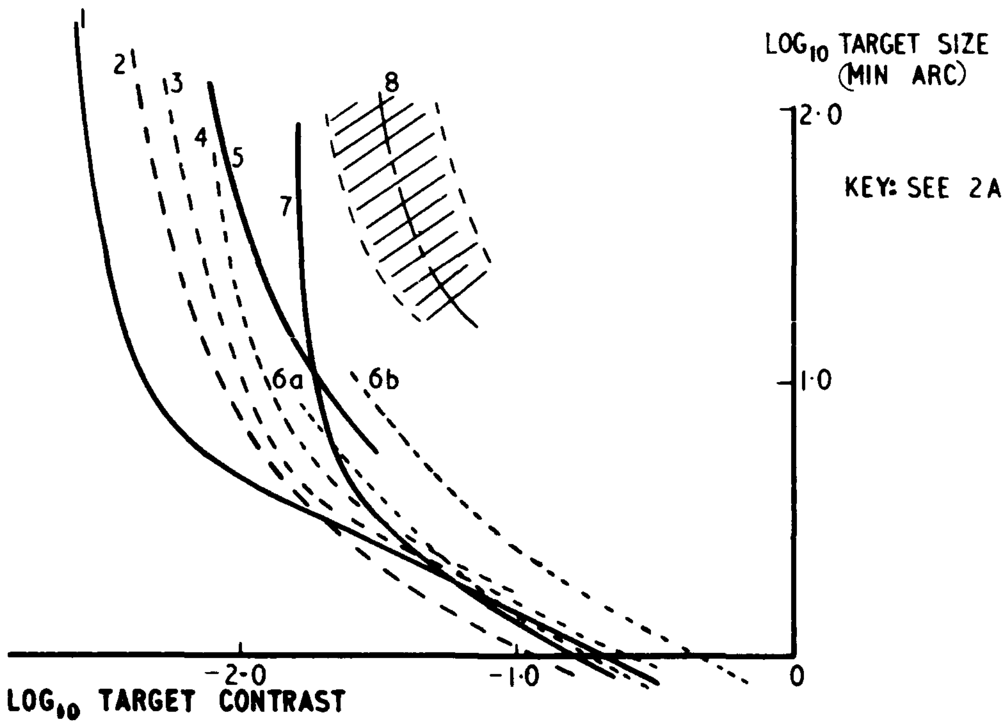

FIG.2 A COLLECTION OF THRESHOLD CURVES FOR THE DETECTION OF DISCS ON A UNIFORM BACKGROUND FOR 'DAYLIGHT' BACKGROUND LUMINANCE

CURVE No	SOURCE (REF)	COMMENTS
1	BLACKWELL[6]	FIXATED VISION. UNLIMITED LOBE TIME FORCED CHOICE. 100 ft.L. DATA ONLY DEPICTED.
2	J.H. TAYLOR.[7]	FIXATED VISION, FORCED CHOICE $\frac{1}{3}$ sec EXPOSURE TIME. 100 ft.L.
3	BLACKWELL & McCREADY[8]	FIXATED VISION, FORCED CHOICE 1 sec EXPOSURE TIME. 100 ft.L.
4	BLACKWELL & McCREADY[8]	AS FOR 3, BUT $\frac{1}{3}$ sec EXPOSURE TIME. (ALSO, AS FOR 2)
5	BLACKWELL[9]	8 POSITION SEARCH IN 6 SECONDS FORCED CHOICE. 100 ft.L. DATA ONLY.
6a 6b	LAMAR etal[10] (ANALYSED IN REF 13) "	8 POSITION SEARCH, IN 3 SECONDS FORCED CHOICE. 2950 ft.L. AS FOR 6a, BUT 17·5 ft.L.
7	THE VISUAL LOBE[4] EQUATION	$\epsilon = 17{\cdot}5\,\theta^{\frac{1}{2}} + 19\,\theta/\alpha^{2}$ APPLICABLE TO 'DAYLIGHT' VIEWING.
8	Vos etal[1]	8 POSITION SEARCH, SLOWLY INCREASING STIMULUS. FREE CHOICE. DATA PRESENTED INCLUDING SUBJECT 'RANGE'

FIG 2A: KEY TO FIG 2

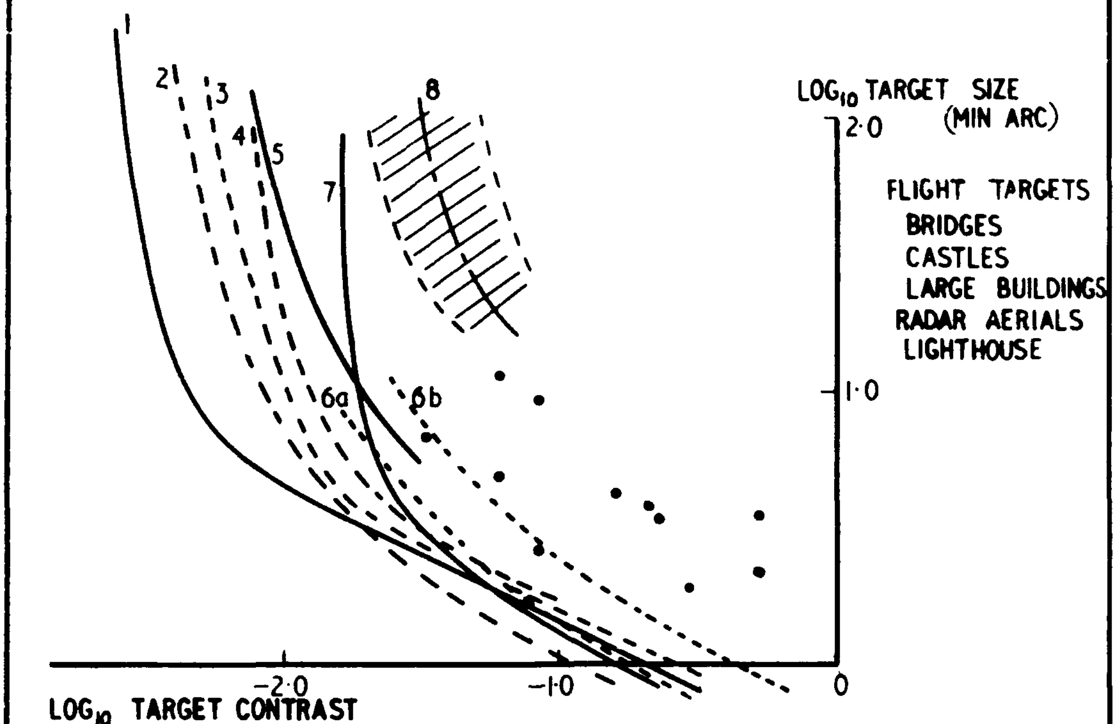

FIG 3 FOVEAL CONTRAST/SIZE THRESHOLDS FROM AN AIR-TO-GROUND DETECTION EXPERIMENT COMPARED WITH THE LABORATORY DATA

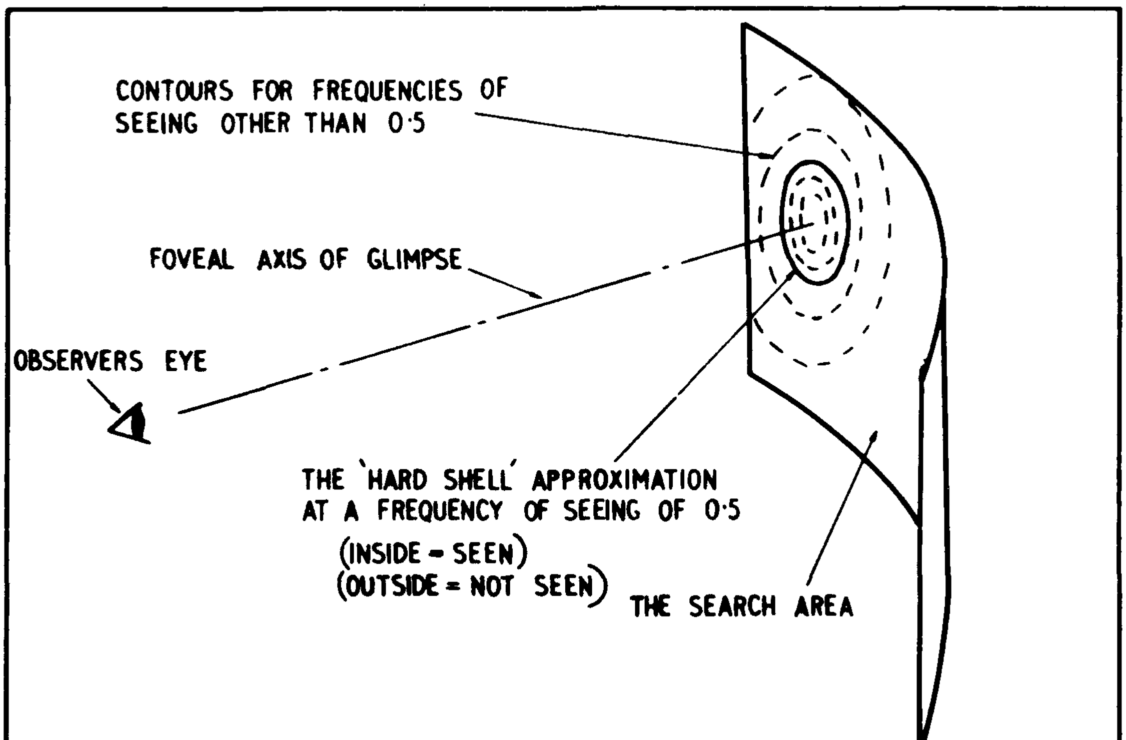

FIG 4 SINGLE GLIMPSE DURING SEARCH WITH CONTOURS FOR THE FREQUENCY (PROBABILITY) OF SEEING A GIVEN TARGET IF SITUATED ON THOSE CONTOURS

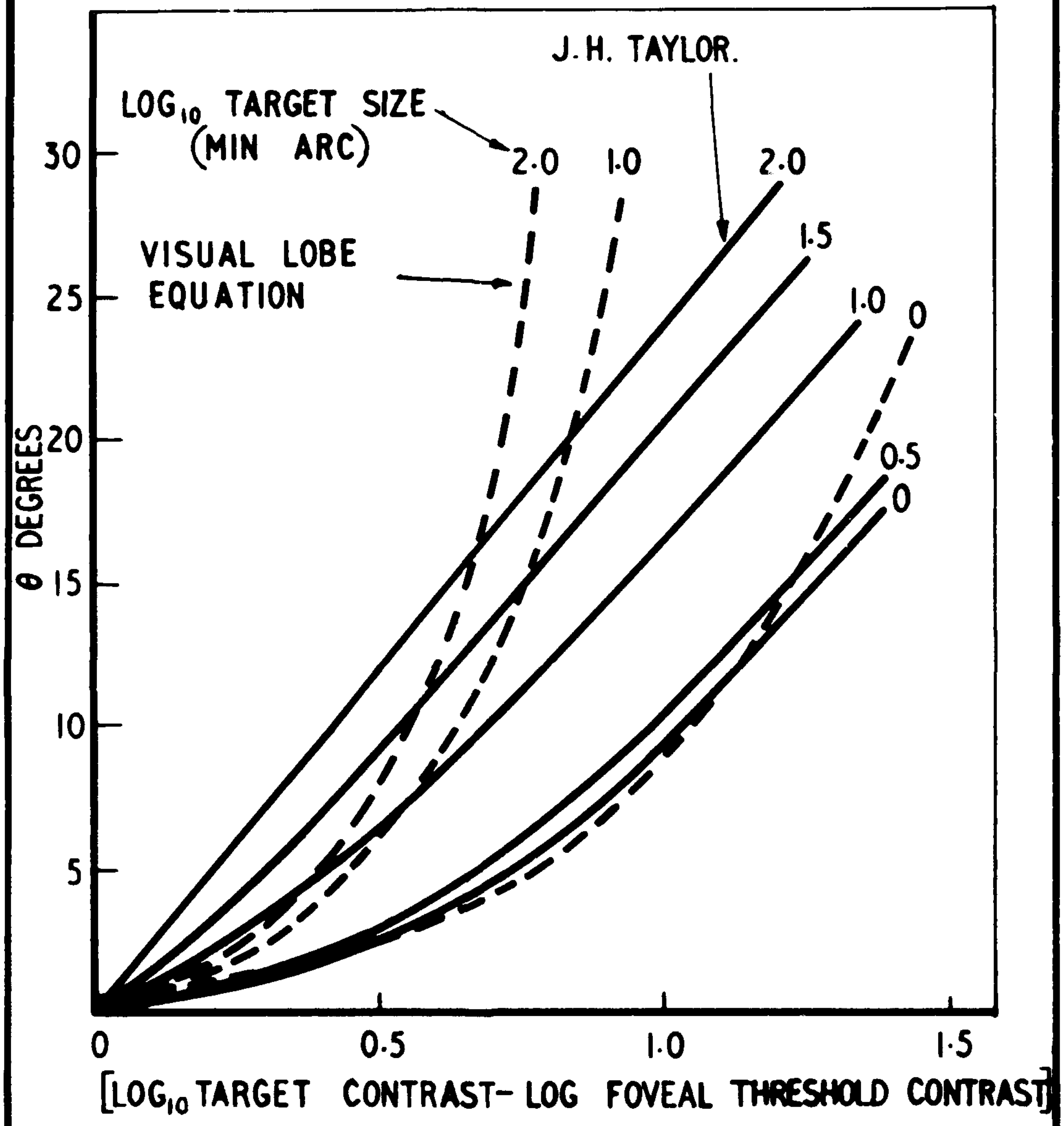

FIG 5 DATA ON THE EXTRA CONTRAST REQUIRED FOR A TARGET TO BE VISIBLE AT θ DEGREES OFF THE FOVEAL AXIS

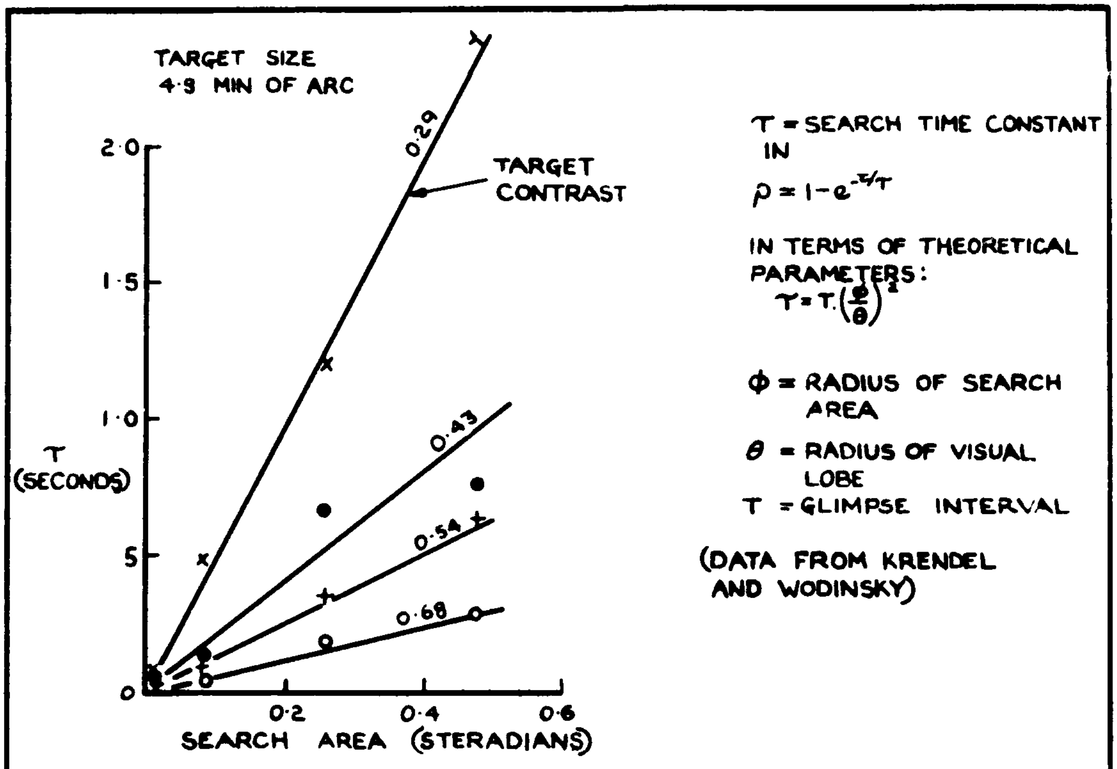

FIG.6A PLOTS OF SEARCH TIME CONSTANT τ AGAINST SEARCH AREA SIZE

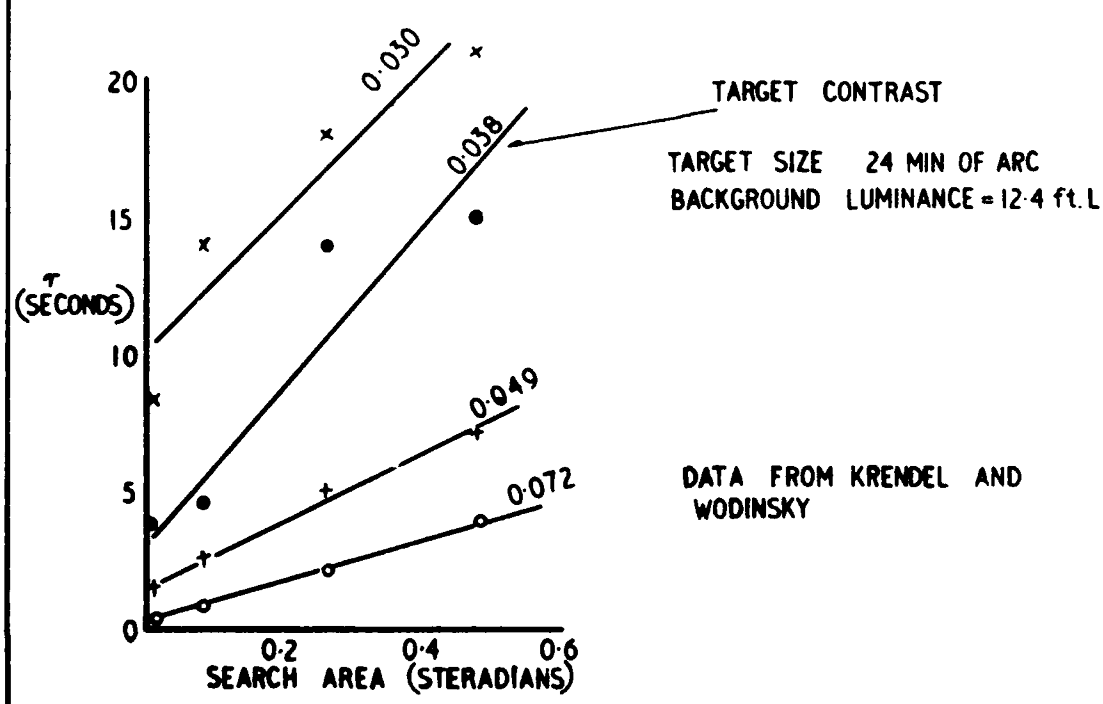

FIG.6B AN EXAMPLE OF $\tau - \phi^2$ GRAPHS WHICH DO NOT GO THROUGH THE ORIGIN

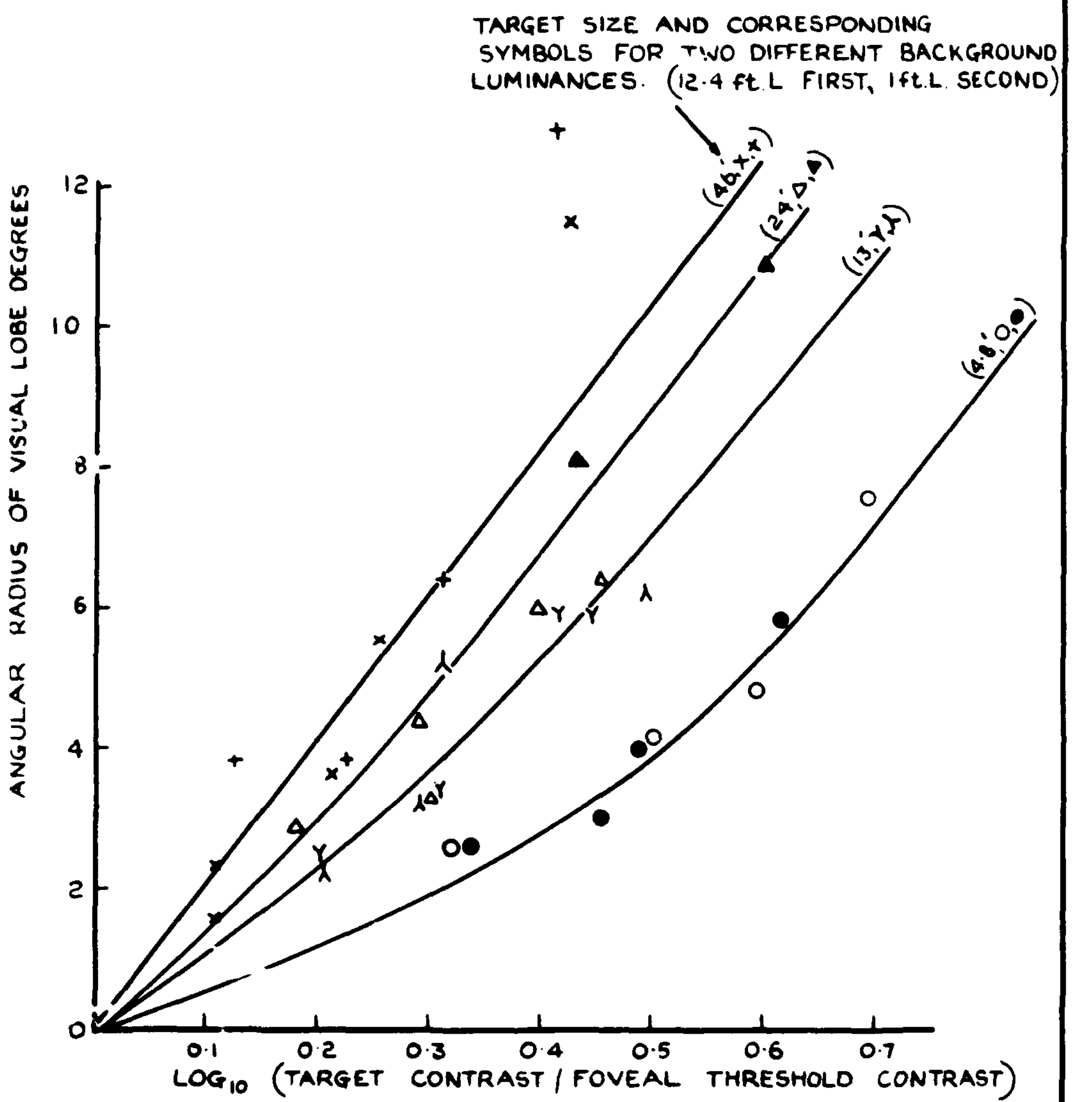

FIG.7 COMPARISON OF THE EXPERIMENTAL VISUAL LOBE RADII WITH J H TAYLOR'S DATA[THE FOVEAL THRESHOLDS ARE ADJUSTED FOR BEST FIT AT EACH TARGET SIZE AND THE GLIMPSE TIME IS TAKEN TO BE $\pi/10$ SECONDS]

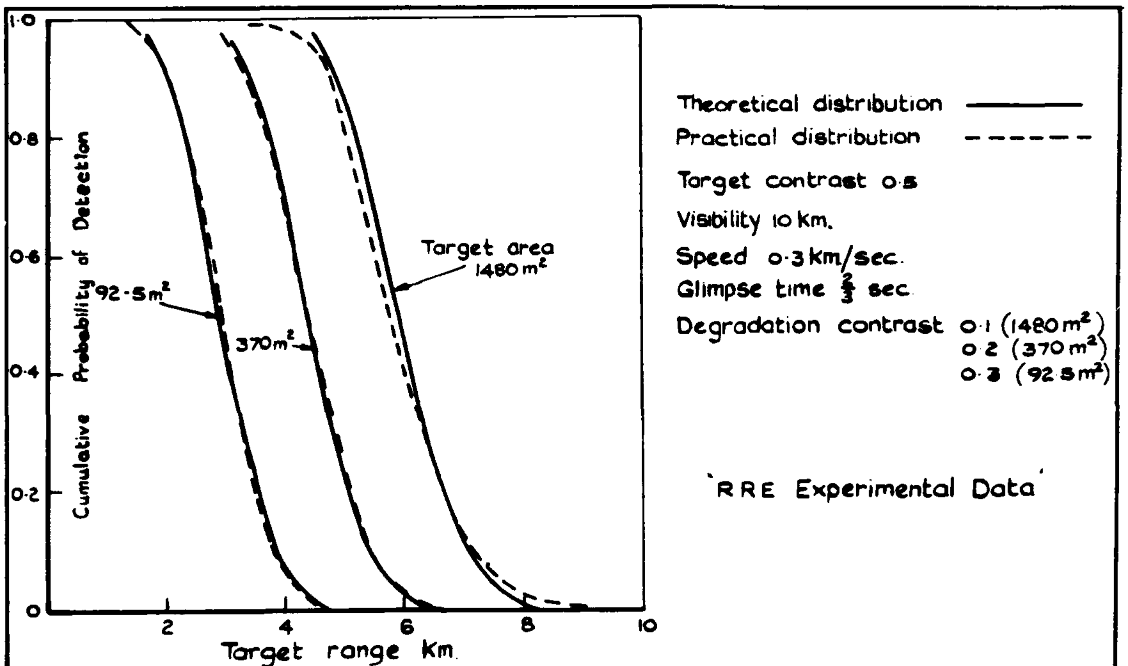

Fig. 8 Comparison between the theoretical and practical effect of target size (2/3 sec. glimpse time and optimum degredation constant)

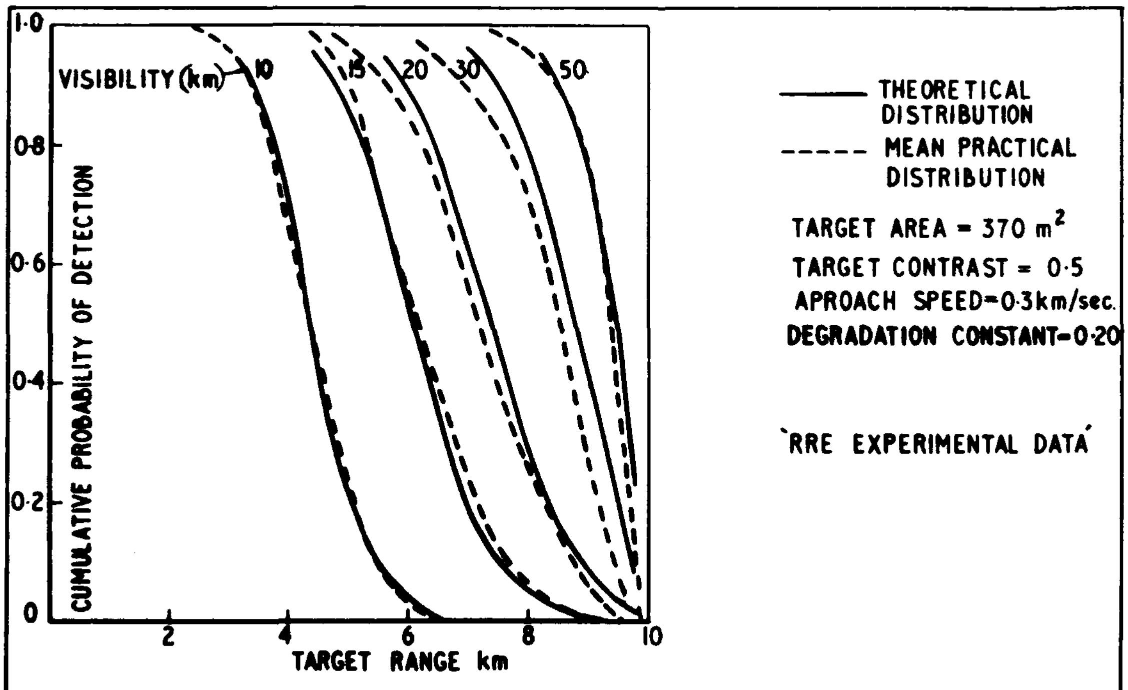

FIG. 9 COMPARISON OF THEORY AND EXPERIMENT FOR THE EFFECT OF VISIBILITY.

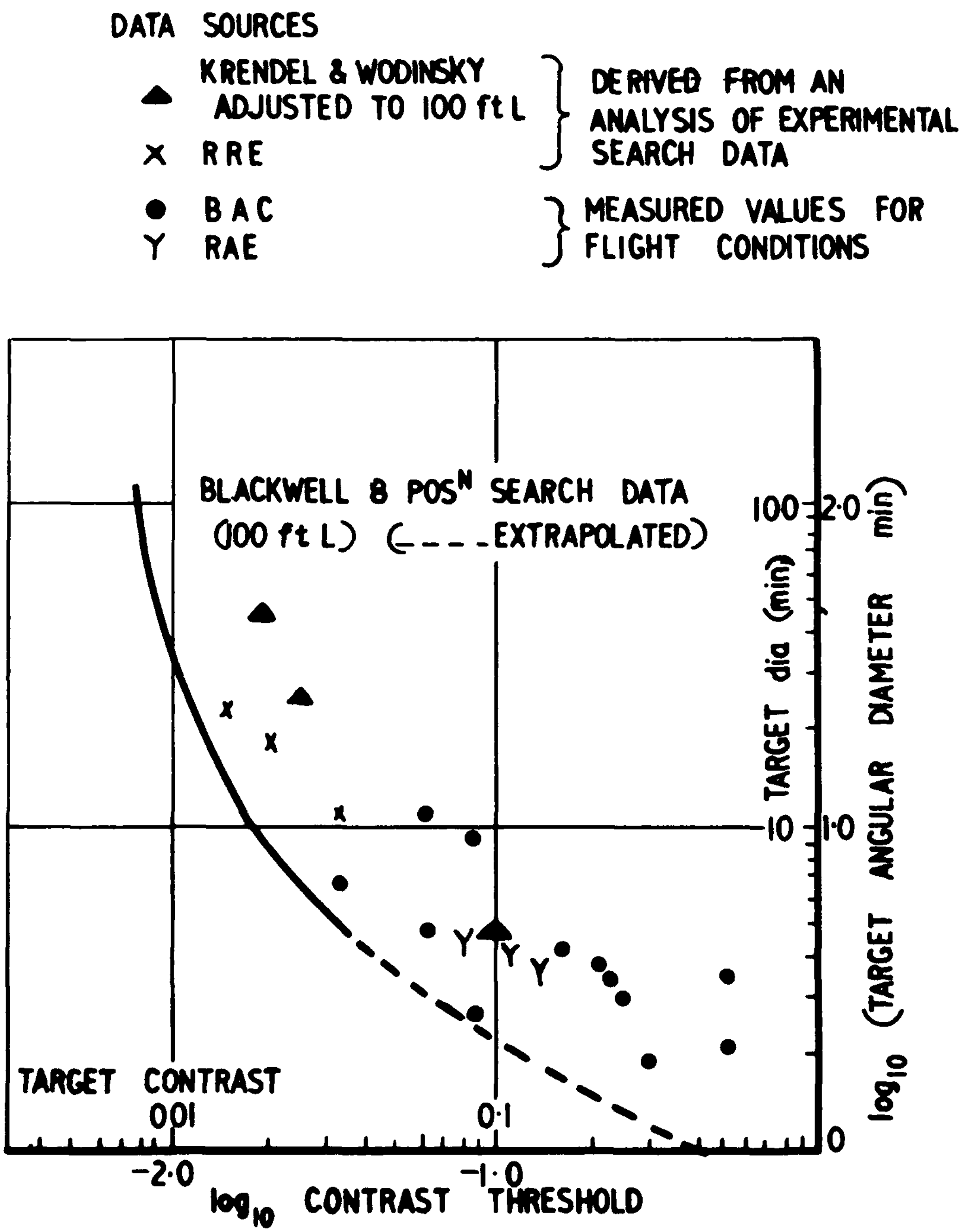

FIG.10 FOVEAL THRESHOLD DATA EXTRACTED FROM THE ANALYSES OF TWO LABORATORY SEARCH EXPERIMENTS AND TWO FLIGHT EXPERIMENTS

TOWARDS A THEORY OF VISUAL SEARCH

by

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SUMMARY

As part of a fuller programme of research into the nature of visual search, we have devised a simple, adaptable search task in which subjects look for the odd disc in a display of larger or smaller discs. We have carried out extensive studies of well practised observers, producing much basic search data.

We have derived a model of search from basic search theory which, while being in no way definitive, is mathematically simple, and, to some extent, accounts for the data we have found experimentally. However, there are some problems, and this is no more than a first step in a continuing effort to devise ways of predicting the range and latency of real targets from a physical specification of the target-background complex.

1. SEARCH DETERMINANTS

Search occurs when a target cannot be located immediately. There are several reasons why search may be necessary.

(a) OBSTRUCTION The target may be completely, or partially, obscured. In this case visual search alone may not be sufficient, though it may enable the observer to deduce the most likely place for the target. To make a positive detection, visual search may have to be augmented either by bodily or manual search; i.e. the observer may have to move himself or move the obstructions until a clear view of the target is possible. When an unobstructed view has been obtained, if search is still necessary it will be for one of the reasons below.

(b) DISTORTION In this case, too, visual search may not end in detection of the target, though the observer may be able to estimate the extent of the distortion by recognising non-target stimuli. Often, detection of a distorted target may only be possible, after the observer has been familiarised with possible distortions or has had practice in the particular situation. If search is still necessary after the observer has learnt how to deal with distortion effects, it will be for one of the reasons below.

(c) SIZE The target may be hard to detect, because it is very small relative to the total search area.

(d) EMBEDDEDNESS The target may not be immediately detectable, because it does not emerge perceptually from its immediate background: there is very low contrast between target and background. Both the case of a weak near threshold target in a plain or noisy background, and that of a camouflaged target in a complex background are included in this category.

(e) COMPETITION Here the target is clearly distinguishable from its immediate background, but it is difficult to detect because it is confusable with non-target stimuli. The problem is one of discrimination and, obviously, the greater the differences between the target and the other stimuli, the easier the task.

In practice search may be necessitated by any combination of these reasons.

2. EXPERIMENTAL APPROACH

We have tried to produce a solid body of data, which can be used, either as the basis for the development of search theories, or to test existing theories. We have looked in detail at the Competition case. Here the target may differ from the non-target stimuli along one or more of the following dimensions: (i) colour, (ii) intensity, (iii) shape and (iv) size. Also other variables, such as the (v) number, (vi) density and (vii) distribution of non-target stimuli, must be considered. There has been little systematic investigation of these variables. Smith (1962) used several different target shapes (triangle, square, pentagon and hexagon) with circles as non-target stimuli. He also varied the density of the stimuli. Brody, Corbin and Volkmann (1960) investigated the number of stimuli - they held the density constant, so display size increased with number. Williams (1967) has varied the colour, size and shape of his stimuli, but, in his work, it is difficult to assess the effects of these variables, because his targets were designated by two-digit numbers (placed in the centre of particular target stimuli) and he did not report search times (instead recording the numbers of fixations falling on stimuli of various colours, shapes and sizes).

We have looked in considerable detail at size differences and, in our next series of experiments hope to relate these to shape differences.

3. EXPERIMENTAL METHOD

Using an overhead projector, thin perspex sheets, in which shallow holes have been drilled, and ball bearings of various sizes, we have devised a technique for search experiments that enables us to undertake extensive studies on well practised observers. The search task has been to find a disc of different size from the other discs in a particular display. We have recorded search times as we have varied the target-non-target size difference, and now have data for a wide range of conditions. These include: searches with all targets bigger than the non-target stimuli, searches with all targets smaller, and searches with some bigger and some smaller; comparisons between search among regularly and irregularly arranged stimuli, and comparisons between search in displays that vary in the density of non-target stimuli. Data has been obtained for targets placed in displays where the non-target stimuli include several different sizes of disc, and for search when the observer has not known which of several targets to expect. Typical results of varying target-non-target size differences are shown in Figures 1 and 2. The data shown is for a regularly arranged matrix, with the largest discs as non-target stimuli and six smaller discs as targets. In Figure 1, mean search time is plotted against the target-non-target size difference, expressed as a percentage of the non-target size. In Figure 2 the cumulative distribution of the search times for the six targets is shown.

4. THEORETICAL APPROACH

We have attempted to extend basic search theory to account for the effects we have obtained experimentally. Like most search theorists we have made several assumptions: (i) that detection of a target only occurs in fixation periods; (ii) that the eye is most sensitive along the line of sight and that the target can only be detected if it is within what is usually known as the visual lobe, i.e.

within a small part of the visual field close to the line of sight (see paper A:1 in these proceedings by Dr. E. B. Davies for more details); (iii) that a section through the visual lobe at right angles to the line of sight will be circular (see section 6:1 for a discussion of this assumption); (iv) that the time for a single fixation can be reasonably represented by an average fixation time, 'ts' (see section 6:2 for a discussion of this assumption) and that the probability of detecting the target in a single fixation can be represented by the average probability, 'ps' - both 'ts' and 'ps' remaining roughly constant under constant conditions (same observer, same illumination, same type of display, same display distance).

Then after 'n' fixations the probability of detecting the target, pn, is given by:

$$pn = nps, \quad \text{for efficient, regular search}$$

$$\text{or} \quad pn = 1 - (1-ps)^n, \quad \text{for independent, random search} \qquad (1)$$

The mean number of fixations, $\bar{n}$, required to detect a randomly placed target is given by:

$$\bar{n} = \tfrac{1}{2}\left(\frac{1}{ps}+1\right), \quad \text{regular}$$

$$\text{or} \quad \bar{n} = \frac{1}{ps}, \quad \text{random} \qquad (2)$$

Now, the mean search time, $\bar{t}$, equals the mean time for fixations plus the mean time for saccades between fixations. Ignoring the latter, which is, comparatively very small, we have:

$$\bar{t} = \bar{n}.ts \qquad (3)$$

From (2) and (3):

$$\bar{t} = \frac{ts}{2}\left(\frac{1}{ps}+1\right), \quad \text{regular}$$

$$\text{or} \quad \bar{t} = \frac{ts}{ps}, \quad \text{random} \qquad (4)$$

The average probability of detection, ps, is related to the average area, a, covered by the visual lobe in a single fixation and to the search area, 'A', as follows:

$$ps = \frac{a}{A}.L \qquad (5)$$

where 'L' is the probability that if the target falls within 'a' it will be detected.

From (4) and (5):

$$\bar{t} = \frac{ts}{2}\left(\frac{A.L}{a}+1\right), \quad \text{regular}$$

$$\text{or} \quad \bar{t} = \frac{ts.A.L}{a}, \quad \text{random} \qquad (6)$$

Up to this stage, nothing has been added to basic search theory, although the equations are not usually expressed in this form. If they were, we would have expected this simple relation to have been empirically validated. As it has not, we are, at present, attempting to do this, by directly determining '$\bar{t}$' and 'ts' during search of a given area, 'A', and determining the extent of 'a', for various values of 'L', for single glimpses, equal in duration to 'ts', at the same search display.

Let the angular distance away from the fovea, at which the target can be detected, be 'θ'. Then, assuming the area covered by the visual lobe in the plain of the search area is circular,

$$a = \Pi\theta^2 \qquad (7)$$

Weymouth (1958) showed that, for a wide range of situations, when visual acuity is measured in linear units, '$\Delta\alpha$', rather than as a reciprocal,

$$\Delta\alpha = m\theta \qquad (8)$$

where 'm' is a constant for a given experimental situation. Figure 3 is taken from Weymouth, and shows this relationship for some visual acuity data obtained by Ludvigh (1941). In our competition situation, we have identified '$\Delta\alpha$' with the difference in diameter of non-target and target discs, so equation (8) becomes:

$$\alpha_B - \alpha_T = m\theta \qquad (9)$$

where α_B is the diameter of non-target discs, and α_T is the diameter of target discs. Recent work in our Department shows directly that this equation does describe the relation between 'θ', the distance between two discs, and the threshold size difference.

From (7) and (9):

$$a = \frac{\Pi(\alpha_B - \alpha_T)^2}{m^2} \tag{10}$$

From (6) and (10):

$$\bar{t} = \frac{ts}{2}\left(\frac{A.m^2.L}{\Pi} \cdot \frac{1}{(\alpha_B-\alpha_T)^2} + 1\right) \quad \text{regular}$$

Or $$\bar{t} = \frac{ts.A.m^2.L}{\Pi} \cdot \frac{1}{(\alpha_B-\alpha_T)^2} \quad \text{random} \tag{11}$$

All the quantities in these two equations are separately determinable. Since 'ts', 'A', 'm' and 'L' should all be constant, equation (11) predicts that a linear relationship should be found between '$\bar{t}$' and $\frac{1}{(\alpha_B-\alpha_T)^2}$ for both regular and random search.

5. COMPARISON BETWEEN THEORETICAL PREDICTIONS AND DATA

5.1 Our search experiments give measures of '$\bar{t}$' and we can calculate $\frac{1}{(\alpha_B-\alpha_T)^2}$. If we plot these two variables against each other the points should fall on a straight line, if they are linearly related. Figure 4 shows this relationship for two subjects, using a regularly arranged stimulus display, with the largest discs as non-target stimuli, and six smaller discs in turn as targets. Figure 5 also shows '$\bar{t}$' against $\frac{1}{(\alpha_B-\alpha_T)^2}$, this time for one subject using an irregularly arranged display, and, in one case, large discs as non-target stimuli with three smaller ones as targets, and, in the other case, the smallest discs as non-target stimuli with three larger discs as targets.

All the experimental data we have plotted in this way produces similarly close correspondence to the theoretical predications.

5.2 We then asked whether a similar relation would hold for a single disc target in a plain back-background: i.e. for either the size or embeddedness search situations. The relation between 'α' and 'θ', for this case can be extracted from Taylor's (1961) off-axis contrast threshold data. From Figure 6, it can be seen that for contrast values 1/10, 1 and 10, for 'θ' between 0^o and 20^o:

$$\alpha - \alpha_0 = m\,\theta \tag{12}$$

where 'α' is the size of the target, 'α_0' is the minimum sized target required for foveal detection at the particular contrast level and 'θ' the number of degrees off the foveal axis at which the target can be detected.

If we substitute equation (12) for equation (9) and proceed as before equation (11) becomes:

$$\bar{t} = \frac{ts}{2}\left(\frac{A.m^2.L}{\Pi} \cdot \frac{1}{(\alpha-\alpha_0)^2} + 1\right) \quad \text{regular}$$

or $$\bar{t} = \frac{ts.A.m^2L}{\Pi} \cdot \frac{1}{(\alpha-\alpha_0)^2} \quad \text{random} \tag{13}$$

Miller and Ludvigh (1960) obtained values of '$\bar{t}$' for subjects searching for black discs against a long, thin, plain white background strip at eye level: i.e. a size search situation. No direct value of 'α_0' can be extracted from their data. However, if we assume it has the, not unreasonable, value of 5 min of arc, '$\bar{t}$' against $\frac{1}{(\alpha-\alpha_0)^2}$ is seen, in Figure 7, to be linear.

Encouraged by this finding, an experiment has been carried out in our Department by John Kemp, using a closed circuit television apparatus, in which subjects searched for a disc against a plain background - this was an embeddedness search situation. A direct estimate of 'α_0' was possible, but because the television screen was not homogeneous, the estimation was not accurate. The best estimates suggested 'α_0' lay between 2.0 and 2.5 of the arbitrary units used. Figure 8 shows '$\bar{t}$' against $\frac{1}{(\alpha-\alpha_0)^2}$ for 'α_0' having both of these values

Again some evidence for the linear relationship was found though, obviously, more accurate determination of 'α_0' is required before any confident claims can be made.

5.3 The model of search we have derived, from simple research theory and Weymouth's use of acuity measured in linear units, is mathematically simple and, so far, supported when compared to empirical data. We hope to test the model further with other data obtained both by us and by other workers.

6 PROBLEMS

6.1 There is evidence that 'a', the average area, covered by a section through the visual lobe at right angles to the line of sight, in a single fixation, is not circular, as we have assumed. Chaikin, Corbin and Volkmann (1962) showed that, in a regular matrix of discs, for exposure times between 10 and 200 milliseconds, the shape bounded by a .5 probability contour (i.e. the shape of the section through the visual lobe for L = .5), for detection of a solid triangle, was ovaloid, with the horizontal axis significantly longer than the vertical.

However, it seems unlikely, at the present stage of our theorising, that the adoption of the assumption of circularity, will lead to serious errors in estimating the area of 'a'. Because of this we have held to this assumption, while remaining aware that it is not yet justified. Our current experiment, in which we will determine the extent of 'a' for various values of 'L', will enable us to check the Chaikin et al. finding, and to determine the exact extent of the error involved in this assumption.

6.2 White and Ford (1960) had subjects search for targets that could occur anywhere in a plain circular field of 30° diameter, at any time during a 5 second search period. Figure 9 shows the frequencies of fixation durations for a sample period of the search for 12 subjects. The distribution is not normal, but it would seem reasonable to use the mean fixation time in theoretical work. However, White and Ford give no indication of the difficulty of their task - they do not report search times or detection rates. Nor do they make an attempt to find differences in fixation duration, when a target was actually present - for example if search ends with a longer than usual fixation or with a group of shorter than usual fixations, these fixations should not be combined with others. We have already mentioned our current experiment in which we hope to determine average fixation time, 'ts'. As a preliminary step we must measure fixation time frequencies. From the distribution of these, we will be able to say whether it is in fact justifiable to use average fixation time in the theory, or whether some other measure is necessary.

6.3 It is questionable whether 'ts' remains constant as $(\alpha_B-\alpha_T)$ varies. For example, let us consider the case where this difference increases, i.e. the search task becomes easier, and '$\bar{t}$', mean search time, decreases. If 'ts' did remain constant, 'a' would be expected to increase, thus decreasing '$\bar{t}$' (see equation 6). However, it is as reasonable to suggest that 'a' could be kept constant, with 'ts' decreasing and, again, '$\bar{t}$' would decrease. For this to occur, as $(\alpha_B-\alpha_T)$ increased 'm' would decrease. Since 'm' is defined as "a constant for a given experimental situation" we would then have to say that a change in $(\alpha_B-\alpha_T)$ effectively changes the experimental situation. Perhaps the most reasonable suggestion would be, that 'ts' decreases slightly and 'a' increases slightly to jointly produce a decrease in '$\bar{t}$'. The fact that the relationship between '$\bar{t}$' and $\frac{1}{(\alpha_B-\alpha_T)}$ seems linear, does not necessarily indicate that 'ts' and 'm' were constant, as we assumed. It does, however, suggest that the product of these two terms is constant. Our current experimental assessment of 'ts' for search in which several target sizes are used should clarify this question.

6.4 We would expect detection to improve as the density of non-target stimuli increases. All the evidence contradicts this. Figure 10 shows that search time increases with increasing density in an irregular display. We have produced similar results with a regular display and Brody et al. (1960) and Smith (1962) produced the same density effects.

6.5 Search time distributions are not well described in terms of mean search times. Figure 11 shows why. The data is that already shown for one of the subjects in Figure 4. As search becomes more difficult, in this case as the target size increases towards the largest non-target disc size, mean search times increase, the variability of search times also increases and their distribution becomes highly positively skewed. Some investigators, e.g. Brody et al. (1960), have used median search times. While these are, perhaps, more reliable than means, their use entails that valuable information is ignored. Information that could be preserved, if data is plotted in the form of cumulative distributions. Figure 12 shows, replotted in this way, the data already shown in Figure 4 and Figure 11.

With data in this form the next step is to try to describe it. Equation (1) for the random case:

$$pn = 1 - (1-ps)^n$$

can be written as:

$$pn = 1 - e^{n\log n(1-ps)}$$

This equation suggests that we should be able to fit exponential equations to the cumulative curves. If our cumulative distributions are plotted on semi-log graph paper, and if equation (14) describes them adequately, we would expect to obtain straight lines. Figure 13 shows the distributions in Figure 12 plotted in this way. This fit seems fair, but we hope to be able to estimate the degree to which the data is fitted by exponential equations using computer techniques. More work is required in this area.

6.6 Both equations (1) and (14), on which much of search theory is based, suggest that the cumulative curves should pass through the origin of the graphs, or, at least, have a common origin, whether they

are plotted on ordinary or semi-log graph paper. However, as can be seen from Figures 12 and 13, they neither go through the origin of the graphs nor have a common origin. In an experiment to try to force subjects to go as fast as possible an incentive payment training was used. It can be seen from Figure 14 that a vast improvement in overall performance was obtained, and that, for some targets, the target could be found so quickly that the task could not strictly be called 'search'. However the origins of targets requiring search remain different. Search theories must account for this.

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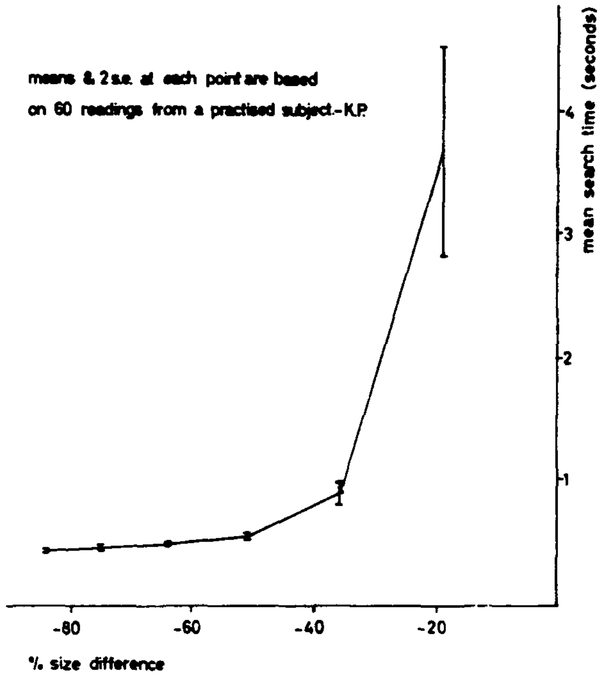

Fig. 1 Effect of varying the size difference between a search target and the non-target stimuli

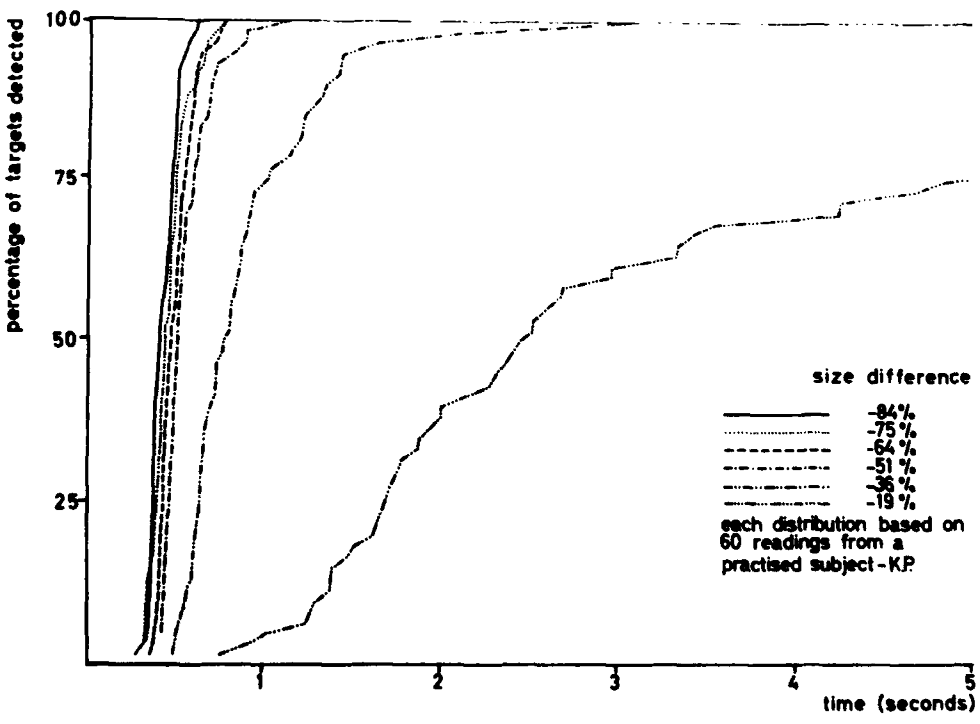

Fig. 2 Cumulative distributions of search times for targets of varying size difference from the non-target stimuli

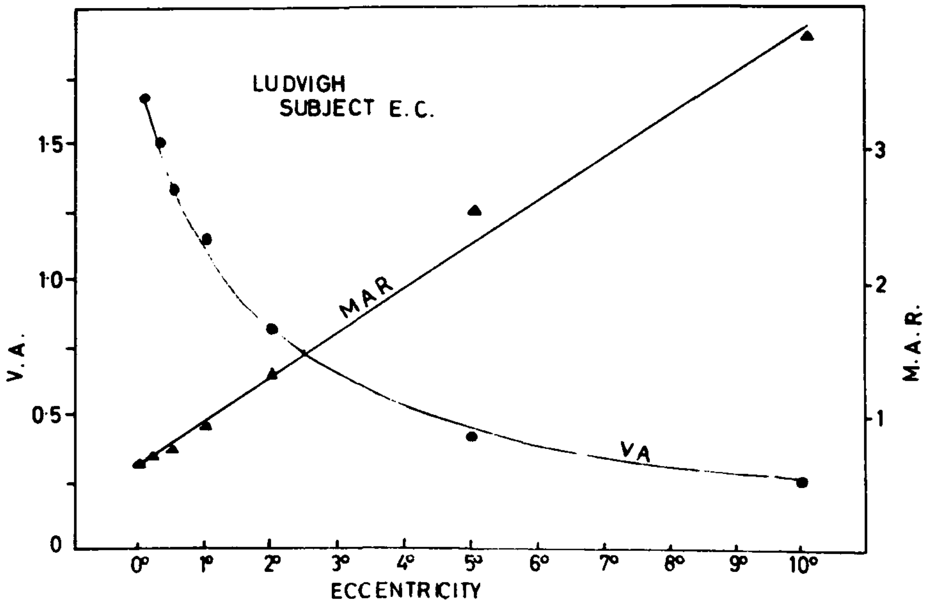

Fig. 3 From Weymouth (1958), replotting data by Ludvigh (1941), showing both that the minimal angle of resolution (M.A.R.) increases linearly with the angular distance away from the fovea at which the stimuli can be detected, and also the usual function for visual acuity (V.A.) which is the reciprocal of the M.A.R.

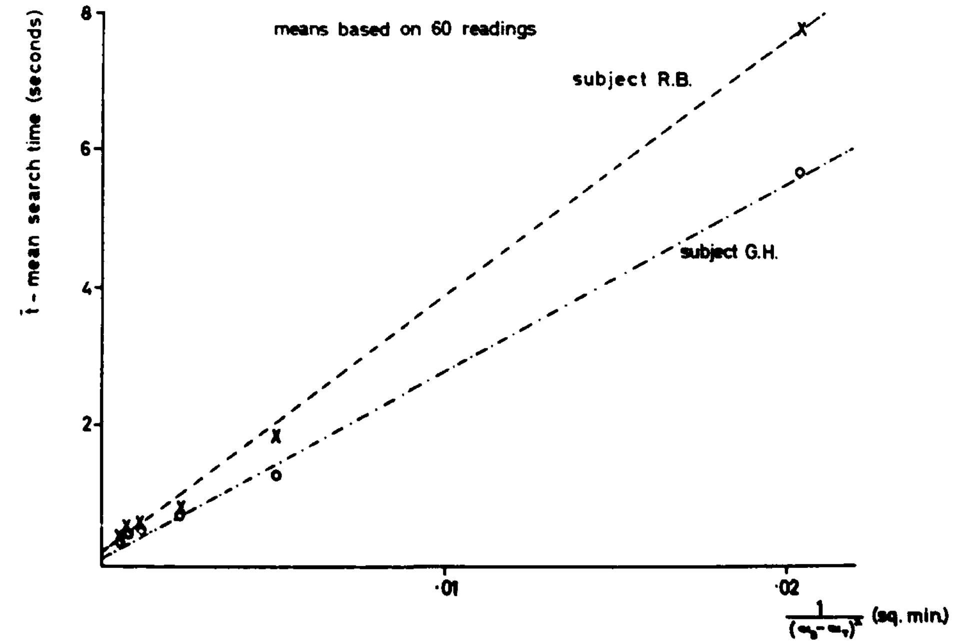

Fig. 4 The relationship between '$\bar{t}$' and $\frac{1}{(\alpha_B - \alpha_T)^2}$ for two subjects searching a regularly arranged display with the largest discs as non-targets

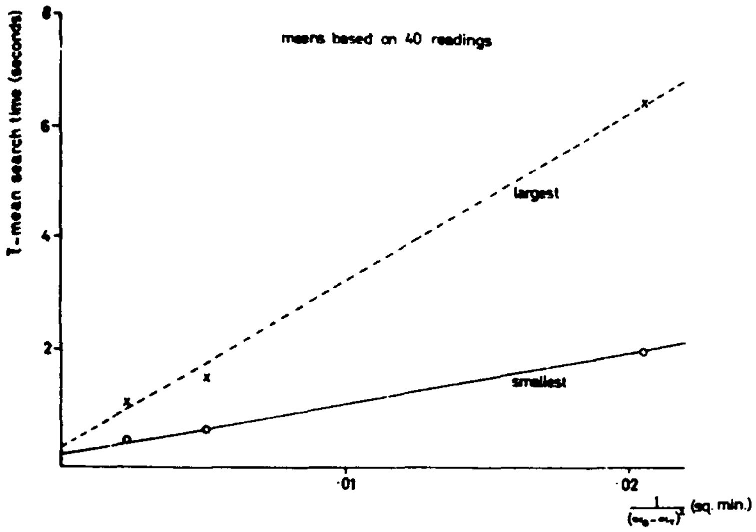

Fig.5 The relationship between '$\bar{t}$' and $\frac{1}{(\alpha_B - \alpha_T)^2}$ for one subject searching an irregularly arranged display with, in one case, the largest discs and, in the other, the smallest as non-targets

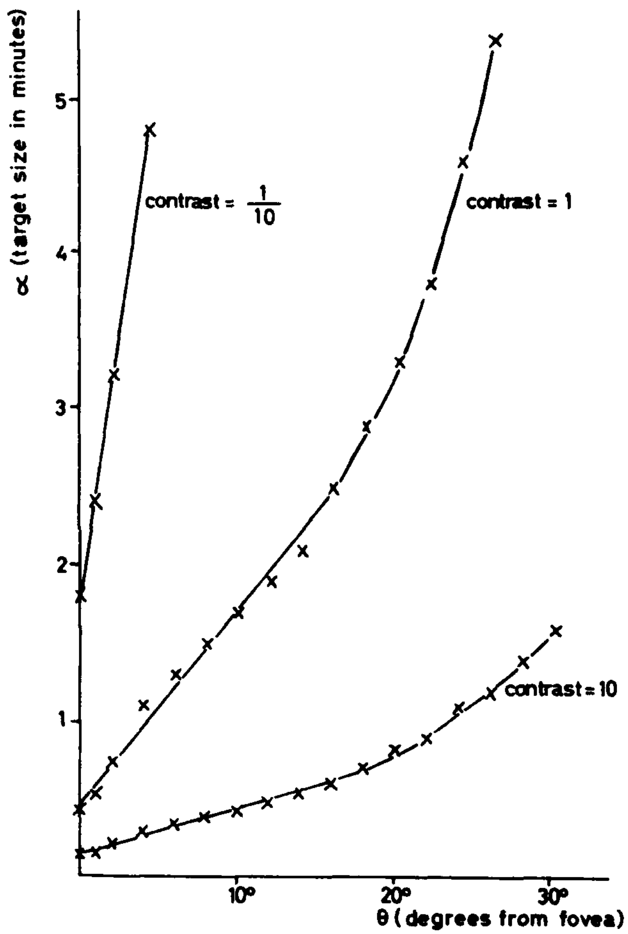

Fig.6 Taylor's (1961) off-axis contrast threshold data replotted to show the relationship between 'α' and 'θ' for three contrast values

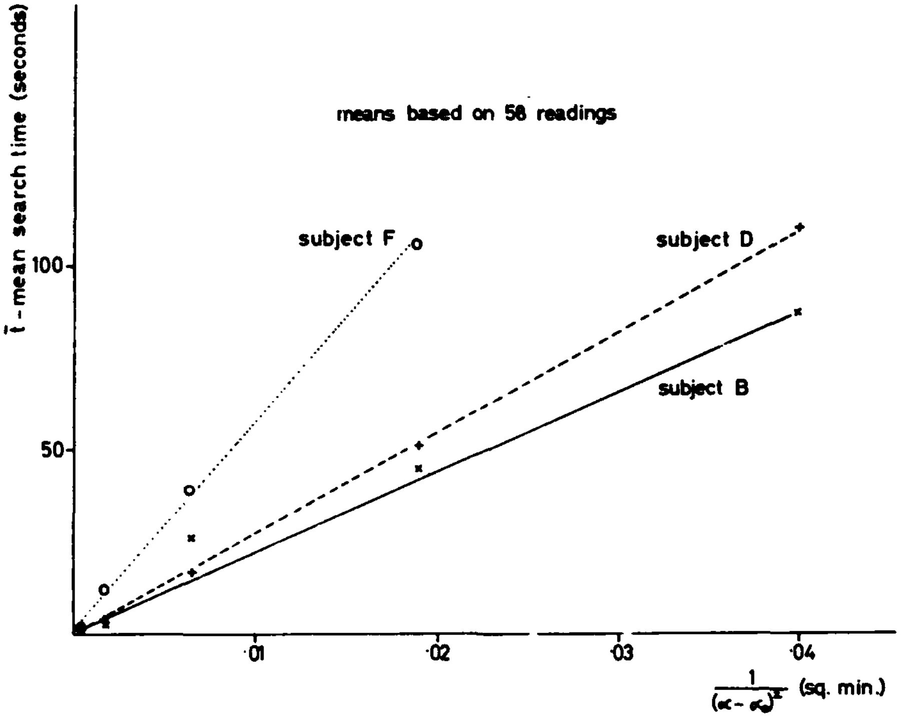

Fig.7 Data from Miller and Ludvigh (1960) replotted to show the relationship between '$\bar{t}$' and $\frac{1}{(\alpha - \alpha_0)^2}$ for search in a plain background - *assuming* α_0 = 5 *min. of arc*

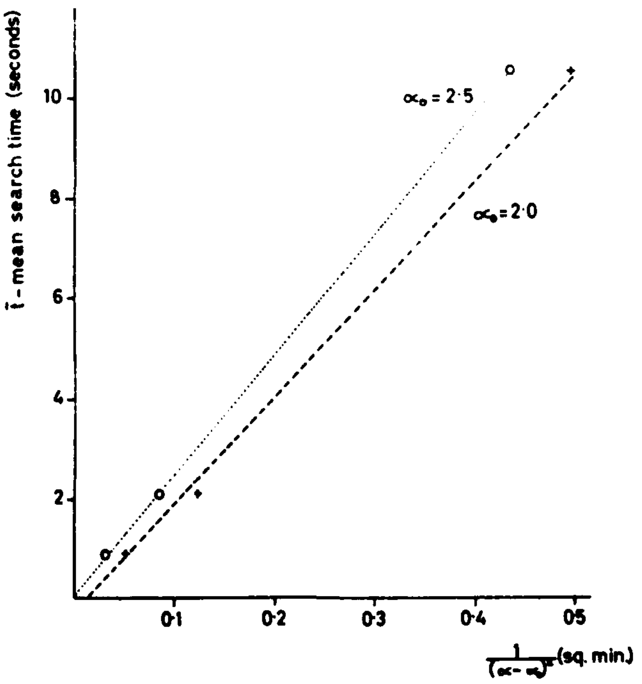

Fig.8 The relationship between '$\bar{t}$' and $\frac{1}{(\alpha - \alpha_0)^2}$, for two values of α_0, for search in a plain background: data collected by J.F.Kemp

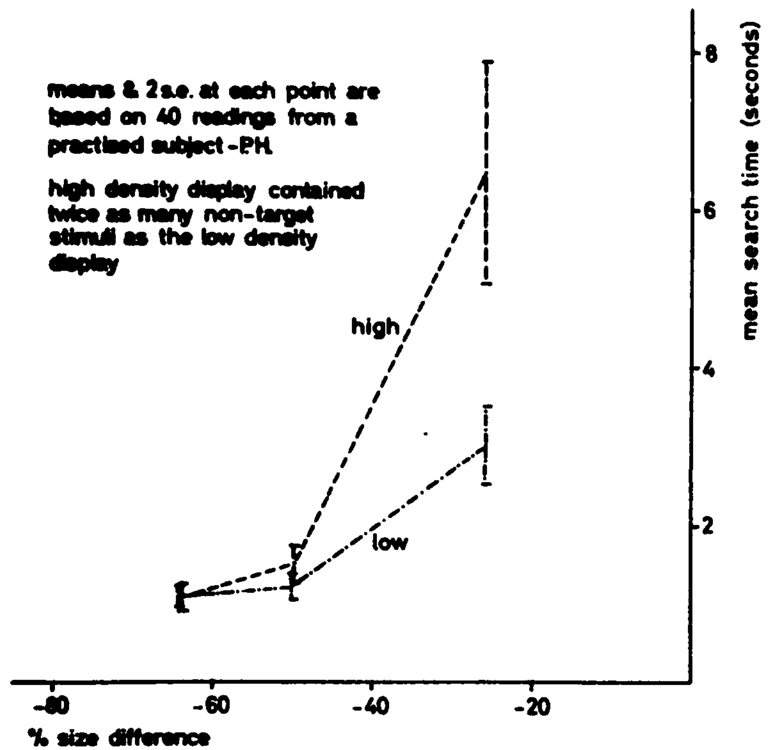

Fig. 10 Shows the effect of increasing display density is greater for the smaller target-non-target difference (i.e. the harder target) in irregular displays

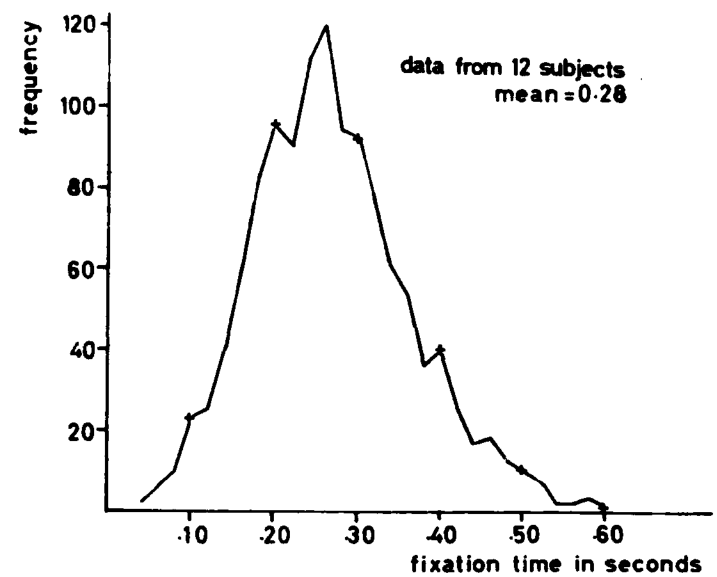

Fig. 9 From White and Ford (1960) showing the frequency distribution of fixation durations during search for a target in a plain background

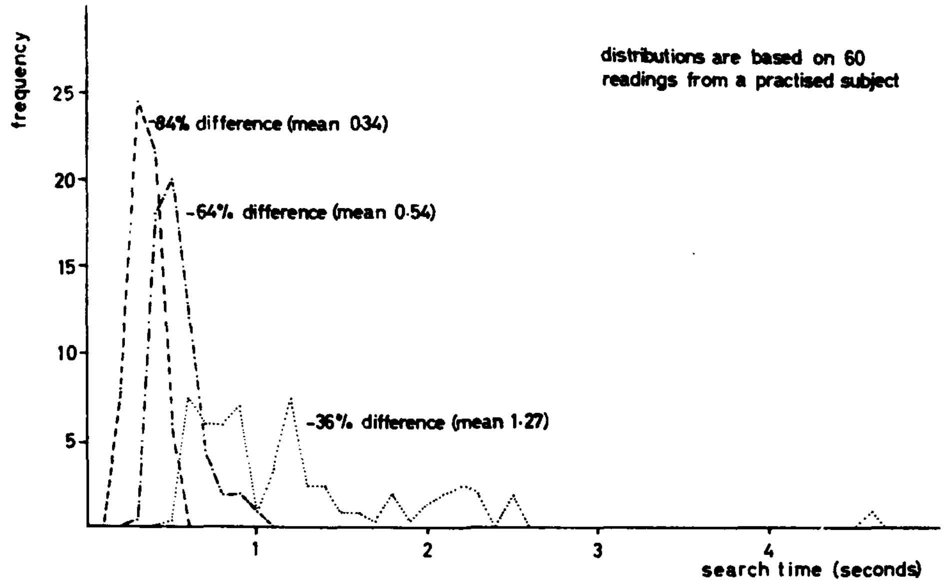

Fig. 11 Shows the frequency distributions of search times for three target-non-target size differences

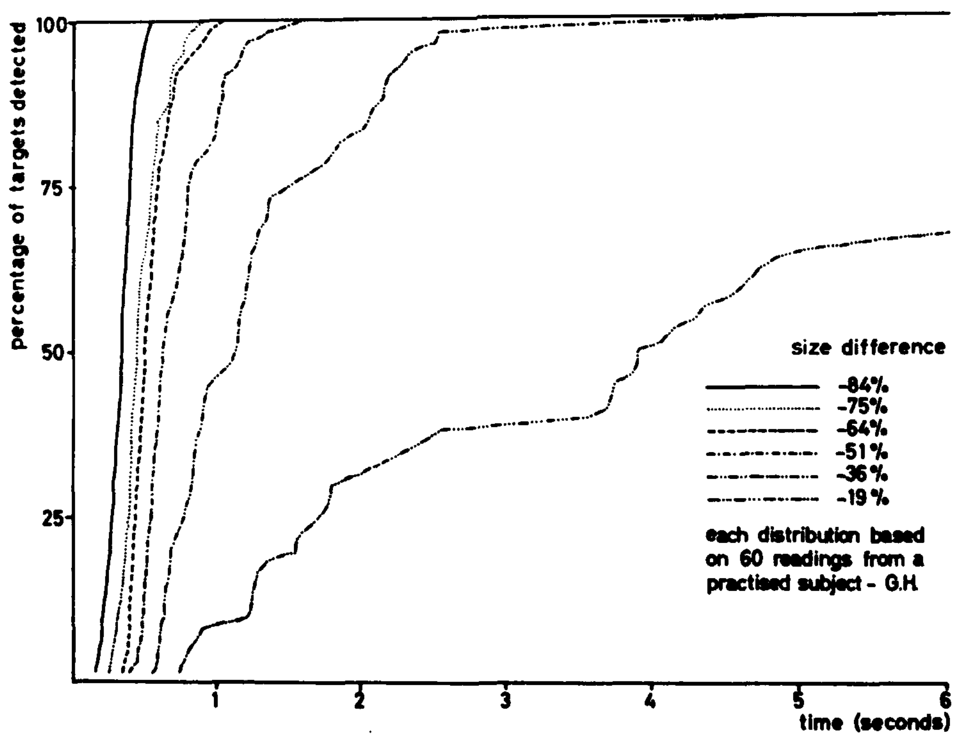

Fig. 12 Cumulative distributions of search times for targets of varying size difference from the non-target stimuli

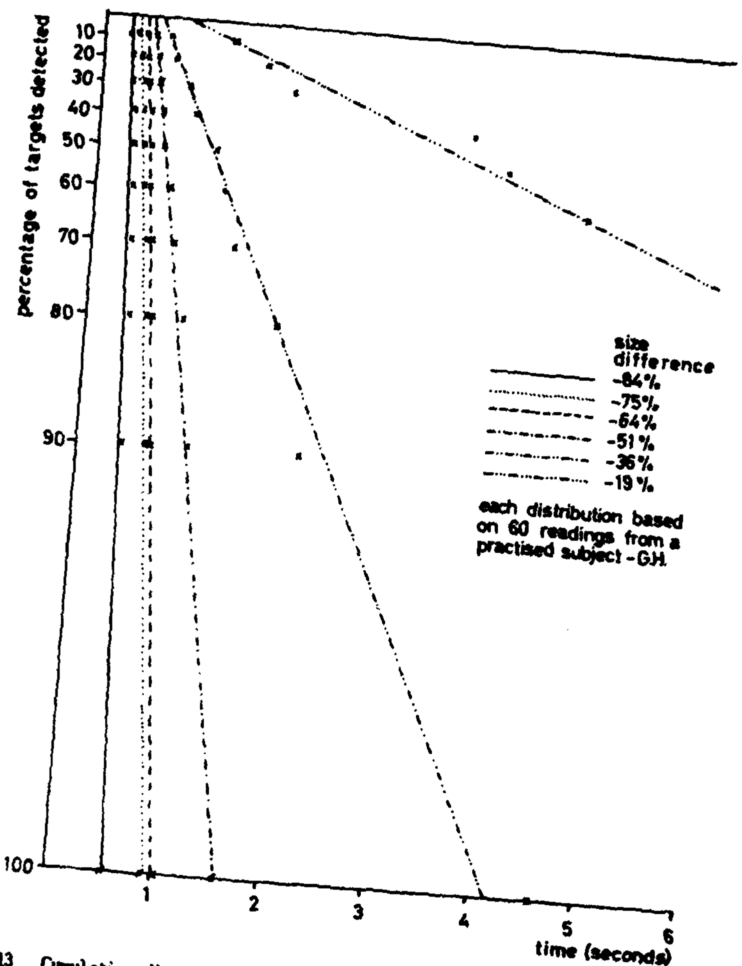

Fig. 13 Cumulative distributions from Figure 12 replotted on semi-log co-ordinates

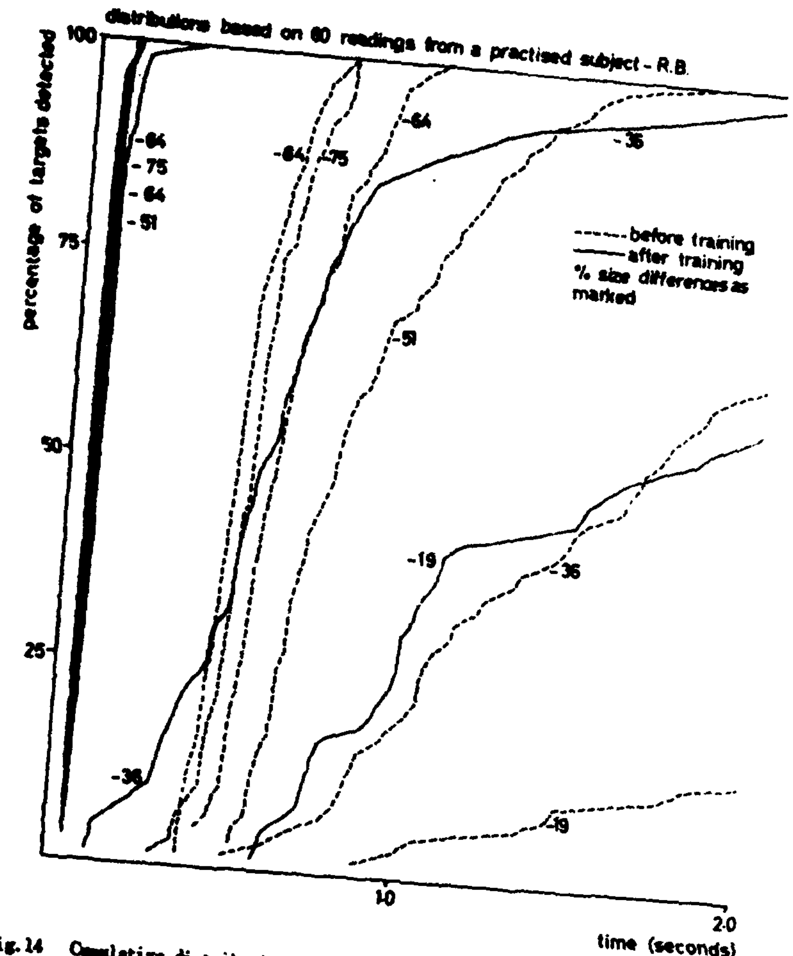

Fig. 14 Cumulative distributions before and after incentive payment training for search in a regular stimulus display

VARIABLES UNDERLYING THE RECOGNITION OF RANDOM SHAPES[1]

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SUMMARY

Previous studies have shown that shape association value (percentage of subjects making an association to a shape) is a strong determining factor in shape recognition. In this study, the physical characteristics of shapes of high and low association value were compared. The intent was to uncover general physical characteristics of shape which differentiate shapes of high association value from shapes of low association value, and, thus, shapes accurately recognized from those not so accurately recognized. Comparisons were made on the basis of 12 factor scores per shape derived from an extensive analysis of 22 physical measures of shape. Results were that none of the factors differentiated between the two classes of shapes. Conclusions were that the physical measures may have been insensitive to perceptually conspicuous features in the perimeters of the shapes, and that associations to a shape are probably too varied in content to expect a few general physical measures to underlie those varied associations.

RECENT STUDIES have shown that an observer's ability to make an association to a shape is a strong determining factor in shape recognition. For example, in a study that I published a few years ago (Clark, 1965), groups of subjects observed 10 simple or 10 complex shapes of high or low association value, and later attempted to recognize them in a forced-choice recognition test. Figures 1 and 2 show the shapes used in that study. All these shapes were selected from a set of 180 uncurved shapes constructed by Vanderplas & Garvin (1959), who used Attneave & Arnoult's (1956) Method 1 for generating random shapes.

You will note that in each figure, the shapes are classified as being of high, medium, or low association value. This measure is defined (Vanderplas & Garvin, 1959) as the percentage of 50 Ss able to make an association to a shape. The mean Vanderplas & Garvin association values and standard deviations for the 10 shapes in each of the three associative categories are shown directly to the right of the word "high," "medium," or "low" in the figures. The number to the left of each row of 5 shapes specifies the number of points plotted in constructing that shape. It denotes the level of shape complexity (Attneave, 1957). In Figure 1, the shapes were constructed using 4 or 6 points and they are called simple shapes. In Figure 2, the shapes were constructed using 16 or 24 points and they are called complex shapes. The number of points plotted usually equals the number of sides in the perimeter of the shape. The number directly under each shape is its Vanderplas & Garvin identification number.

In the recognition study referred to, the subject's first task was to view the 10 simple or the 10 complex shapes of high or low association value shown in the figures. Shapes were presented one at a time on a white projection screen, each for 0.5 sec, with a 3.5 sec interval between shapes. After a brief delay, they attempted to recognize these 10 shapes in a forced-choice recognition test. There were 10 recognition trials. On each trial, the Ss saw two shapes, one at a time, each for 0.5 sec with a 3.5 sec interval between members of a pair. One member of the pair was a previously observed shape and the other member was a distractor shape of the same complexity level. Distractor shapes were selected from the shapes of medium association value shown in Figure 1 and 2. The subjects' task was to write the number "1" or "2" designating whether the first or second shape seen was a previously observed shape. This was done during a 7.5 sec interval between trials. Results of this study were that fewer errors of recognition were made for shapes of high association value than for shapes of low association value and that simple and complex shapes were recognized equally well.

Other studies from our laboratory have corroborated these results and have extended their generalizability. In one study, memory load was increased by having Ss remember 10 simple and 10 complex shapes of both high and low association value instead of 10 simple or 10 complex shapes of either high or low association value. Exposure duration was 0.5 sec as in the earlier study, but observed shapes were paired with distractor shapes of the opposite complexity level instead of the same complexity level as before. Results were the same: shapes of high association value were recognized more accurately than shapes of low association value, and simple and complex shapes were recognized equally well. In a replication and extension of this study (Clark, 1968), the effects of exposure duration were examined. One group viewed each shape for 0.50 sec, and another group viewed each shape for 0.25 sec. The effects of association value and complexity were still the same; the effects of exposure duration were insignificant.

Ellis, Muller, & Tosti (1966) have also established that association value has an incremental effect on shape recognition. They point out that perceptual performance depends upon the meaningfulness of the stimuli only to the degree that such stimuli readily elicit a single association, and that additional associations do not contribute to further gain in perceptual performance. In addition, Ellis & Homan (1968) have shown that experimenter-supplied verbal labels enhance recognition performance.

All of these studies demonstrate that an observer's ability to make an association to a shape is a strong determining factor in shape recognition. In the present study I continued my investigation of association value by comparing the physical characteristics of shapes of high and low association value. The intent was to determine if there are general physical characteristics of shape which differentiate shapes of high association value from shapes of low association value, and, thus, shapes accurately recognized from those not so accurately recognized.

METHOD

SHAPES COMPARED. The shapes compared were the ones you saw in Figures 1 and 2. The complex shapes of high association value were compared with the complex shapes of low association value, and the simple shapes of high association value were compared with the simple shapes of low association value.

SELECTION AND CALCULATION OF THE PHYSICAL MEASURES. Comparisons were made on the basis of 12 factor scores per shape. These scores were obtained from a factor analysis of 12 physical measures of shape derived from 22 other physical measures. The details of the procedures used in calculating all of these measures are described in a report by Knoll & Clark (1968); therefore, I will only summarize the measurement procedures now.

The first step was to select 22 physical measures, most of which have been used in the past (Attneave, 1957; Arnoult, 1960; Vanderplas et al, 1965; Zusne, 1965; Stenson, 1966; Stilson, 1966; Brown & Owen, 1967). All these measures are described in the appendix of this report. Next, each of the 22 measures was taken on four sets of 30 shapes each. These were sets of 4, 6, 16, and 24 sided shapes, respectively, and are the Vanderplas & Garvin (1959) sets from which the shapes in Figures 1 and 2 were selected. The complete sets were measured, instead of just the shapes in Figures 1 and 2, to provide a more representative sample for study.

The technique employed in measuring the shapes was as follows: Each shape was enlarged photographically and the coordinates of the vertices were determined by overlaying the photographs with graph paper. These coordinates were then punched on IBM cards. Finally, the physical measurements were calculated using a computer program written by Knoll & Stenson (1968). This program can be used to generate and/or analyze random shapes.

Based on examination of the correlations and factor structure of the 22 measures, a reduced set of 12 measures for the 120 shapes was derived. These measures appeared to adequately describe the shapes, and they were nearly orthogonal to each other.

The last step was to factor analyze these 12 measures and then calculate factor scores for each of the 120 shapes. Results of a principal-axes factor analysis on the 12 measures are shown in Table 1. Twelve factors, A through L, were rotated. Only loadings greater than .30 are included in the Table, and each loading is rounded to two figures. The decimal point is omitted.

Mathematical symbols for the 12 physical measures are shown in the far left column of Table 1. You will note that each factor in Table 1 can be adequately described in terms of the physical measure having the highest loading on that factor. The 12 sets of factor scores, rather than the 12 physical measures, were used to compare the groups of shapes, because the factor scores are more nearly orthogonal to each other even for a subgroup, than the physical measures, and, thus, permit a clearer interpretation of the sources of variation.

Definitions of the 12 physical measures, and thus the 12 factors, are as follows:

1. Area. The area of the form. (A)

2. Compactness. The length of the perimeter divided by the square root of the area. ($P/A^{1/2}$)

3. Orientation. The length from the positive x-axis to the positive first principal-axis, measured counterclockwise along a unit circle, (with its center at the center of gravity of the form), divided by the circumference of the unit circle. ($D/2\pi$)

4. Adjusted Straight Length Variance. The variance of the distribution of straight lengths in the perimeter of the shape divided by the area. (V_s/A). This measure reflects the diversity in the lengths of straight segments in the perimeter of the shape. The reasons for dividing this measure and other adjusted measures by the area, or powers of moments, was to render the measures more independent of each other and independent of the size of the shape.

5. Adjusted Straight Length Skewness. The skewness of the distribution of the straight lengths divided by the square root of the variance of the distribution of straight lengths raised to the third power. ($S_s/V_s{}^{3/2}$)

6. Adjusted Straight Length Kurtosis. The kurtosis of the distribution of straight lengths divided by the square of the variance of the distribution of the straight lengths. ($K_s/V_s{}^2$)

7. Adjusted Skewness of Internal Angles. The skewness of the distribution of the internal angles divided by the square root of the variance of the distribution of the internal angles raised to the third power. ($S_g/V_g{}^{3/2}$)

8. Adjusted Kurtosis of Internal Angles. The kurtosis of the distribution of internal angles divided by the square of the variance of the distribution of internal angles. (K_g/V_g^2)

9. Elongation. The area variance along the second principal-axis divided by the area variance along the first principal-axis. (μ_{02}/μ_{20}). As a form approaches a straight line, this measure approaches zero. As the form approximates a circle, it approaches 1.

10. First Principal-Axis Symmetry. The area skewness along the first principal-axis divided by the square root of the third power of the area variance along the first principal-axis. ($\mu_{30}/\mu_{20}^{3/2}$). A form with a teardrop shape has a high value on this measure while an ellipse has a zero value.

11. Second Principal-Axis Symmetry. The area skewness along the second principal-axis divided by the square root of the third power of the area variance along the second principal-axis. ($\mu_{03}/\mu_{02}^{3/2}$)

12. Two-Way Symmetry. The area skewness along the second principal-axis divided by the area skewness along the first principal-axis. (μ_{03}/μ_{30})

A clearer understanding of these measures can be obtained by reading the description of the 22 physical measures described in the appendix, and by comparing shapes with high and low values on the measures in both the 12 and 22 measure sets.

STATISTICAL ANALYSIS. Ten complex shapes of high association value were compared with 10 complex shapes of low association value, and 10 simple shapes of high association value were compared with 10 simple shapes of low association value. Comparisons were made using the Mann-Whitney U Test. It was used because the sample sizes were small, and because the test is theoretically insensitive to the distribution of scores in the population.

To supplement the U Test analysis, a correlational analysis was also performed. All four sets of the Vanderplas & Garvin shapes, from which the shapes in Figures 1 and 2 were selected, were included in this analysis. Within each set of 30 shapes, each of the 12 sets of factor scores was correlated with association value. Thus, within each set, 12 correlations were calculated, and each correlation was based on 30 pairs of measures.

RESULTS AND DISCUSSION

None of the 24 U Tests was statistically significant. The 12 factors did not differentiate between shapes of high and low association value for either simple or complex shapes. Results of the correlational analysis were similar. None of the correlations was sufficiently high to suggest a reliable relationship between any single factor, or any group of factors, and association value. The correlations are shown in Table 2. The percent of variance in association value explained by the 12 factors is 30%. This was determined by correlating the association values for the 120 shapes with the corresponding sets of factor scores for the 120 shapes and then squaring and summing these 12 correlations to obtain the percent variance explained. This procedure was possible because the factor scores between factors for the entire set of 120 shapes are orthogonal to each other.

The failure to obtain a significant relationship between association value and our carefully derived physical measures of shape may be interpreted in various ways. From one point of view it may be concluded that the physical measures selected for study were inappropriate, and that the possibility remains of eventually finding physical characteristics which underlie association value as defined in this study. For example, it is possible that subjects make a majority of associations to perceptually conspicuous portions of the perimeter of the shape rather than to general characteristics of the whole shape. If so, our measures were inappropriate. None gave particular emphasis to salient characteristics of the perimeter. Relevant to this point of view are results by Zusne (1965). He has pointed out that the physical measures he has used in discrimination studies have not given sufficient weight to the perceptually conspicuous portions of the perimeter. Therefore, he recommends weighting these parts of the perimeter more than its other parts. The problem with this approach is determining which parts of the perimeter should be classified as "salient."

From another point of view, it may be suggested that association value, as defined in this study, should not necessarily correlate with any general, or specific, physical characteristics of shape. The thesis of this point of view is that associations are too varied in content to expect a few physical measures to underlie all of them. Data that I have collected indicate that associations to shapes are, indeed, often varied. Ten people may give 10 different associations

to the same shape. Perhaps it is unlikely that only a few measures of shape underlie all these associations. Possibly, a different measure of association value, which accounts for the variety among associative responses, would be more likely to correlate with physical measures of shape. A major problem in deriving this new measure of association value, however -- which, by the way, we would want to correlate with recognition accuracy -- is determining which associative responses should be classified as "different" from each other.

Clearly, additional research is required if we are to find all the variables underlying the recognition of random shapes. The research task becomes even greater when we attempt to specify the variables underlying the recognition of targets from aircraft and spacecraft. We are a long way from that goal. Nevertheless, this is the goal, and many investigators are working toward it.

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TABLE 1

Simple Structure Factor Matrix
for the 12 Physical Measures

	A	B	C	D	E	F	G	H	I	J	K	L
1. Area	-34								35		82	
2. $P/A^{1/2}$							95					
3. Orientation					99							
4. V_s/A									-93			
5. $S_s/V_s^{3/2}$										-94		
6. K_s/V_s^2			-91							-31		
7. $S_g/V_g^{3/2}$		-93										-33
8. K_g/V_g^2		-40										-90
9. μ_{02}/μ_{20}	-93											
10. $\mu_{30}/\mu_{20}^{3/2}$						-98						
11. $\mu_{03}/\mu_{02}^{3/2}$								98				
12. μ_{03}/μ_{30}				98								

TABLE 2

Correlations Between Association Value
and Factor Scores for 4, 6, 16 & 24 Point Shapes

Factors	4	6	16	24
A	-.14	-.11	.33	-.05
B	-.36	.24	.04	.37
C	.16	-.20	-.17	-.24
D	-.41	.09	-.09	-.23
E	-.19	.09	.14	-.10
F	-.06	-.44	-.08	-.04
G	.29	.16	.15	-.23
H	.05	-.43	.10	.06
I	-.29	-.24	.23	-.19
J	.02	.38	.23	-.18
K	.06	-.07	.01	-.30
L	.05	.42	.09	-.19

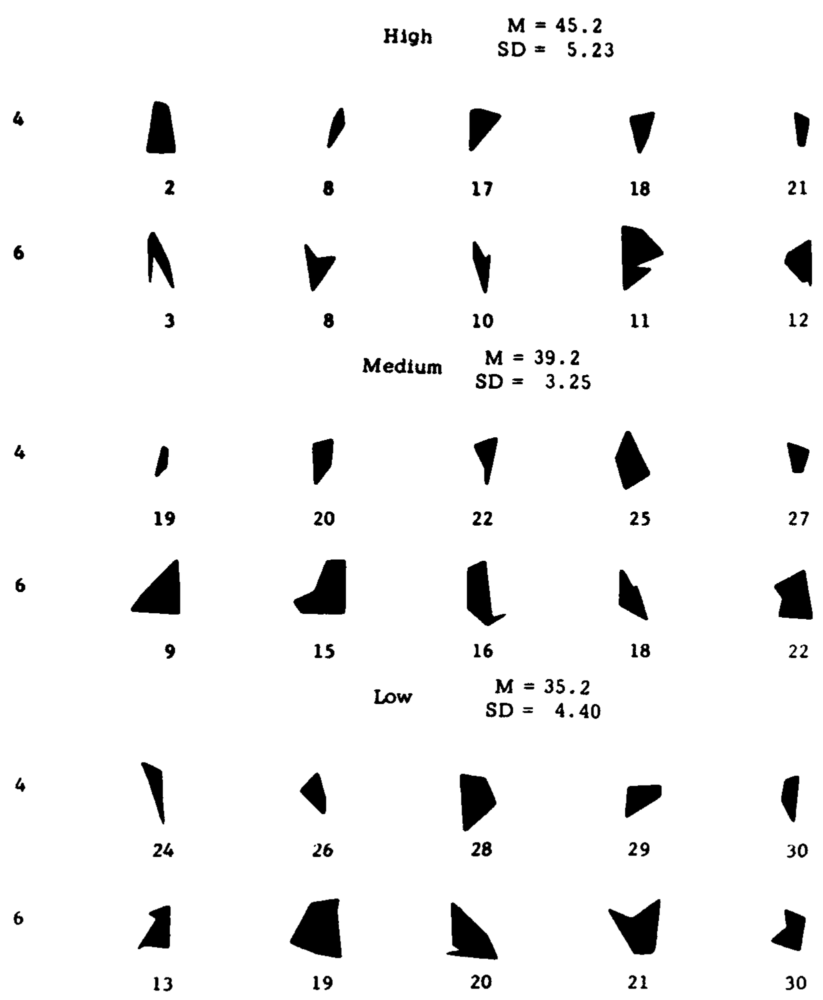

Figure 1. Simple Shapes of High, Medium, and Low Association Value

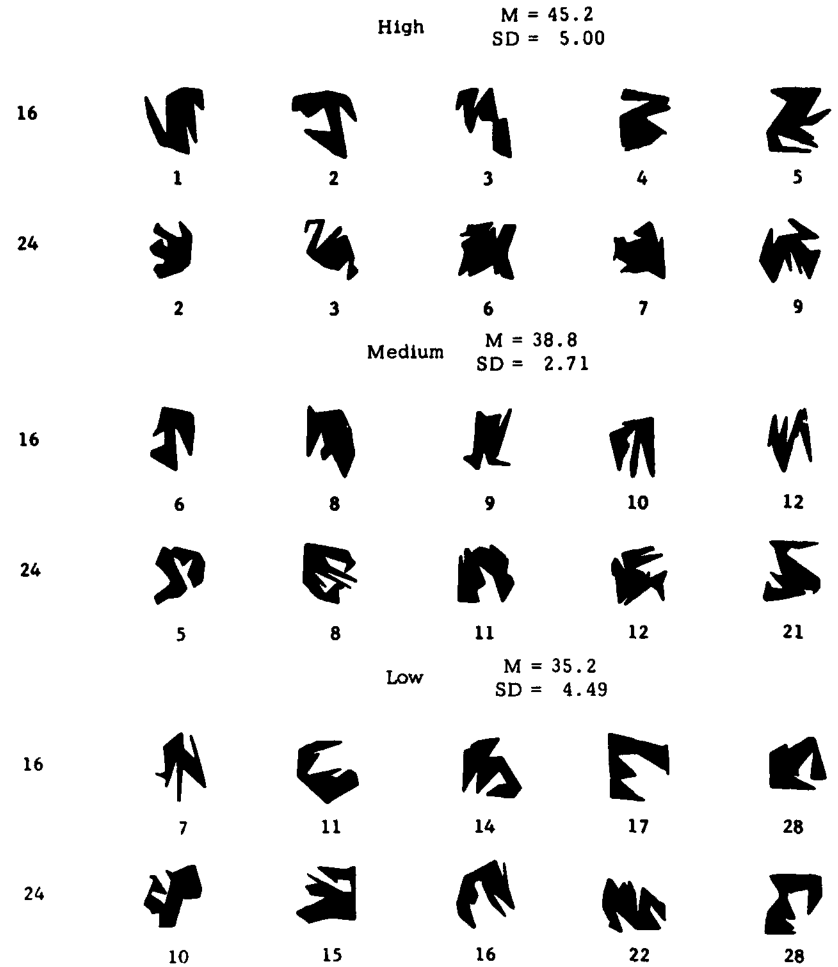

Figure 2. Complex Shapes of High, Medium, and Low Association Value

APPENDIX

Unless otherwise noted, these measures are defined in terms of the grid units used in the construction of the stimuli.

1. Turns. The number of turns in the contour of the shape. The number of points plotted to construct a shape determines the number of sides in the perimeter of the shape; these are usually equal. (T)

2. Convex Turns. The number of turns at which the angle (measured interior to the form) is less than π radians. (T_c)

3. Perimeter. The length of the perimeter. (P)

4. Area. The area of the shape. (A)

5. Orientation Angle. The angle (in radians) formed by the positive x-axis of the construction grid and the positive first principal-axis of the form. The first principal-axis of a form is defined as that axis along which the form has maximum variance of area.[1] The second principal-axis is defined as that axis perpendicular to the first principal-axis such that the pair of axes form a righthanded coordinate system. The positive direction of the first principal-axis was defined by requiring that the skewness of the area along the first principal-axis be greater than or equal to zero. The first product moment of area for the principal-axes coordinate system is always equal to zero. The angle is measured counterclockwise from the x-axis to the first principal-axis and the range of the measure is 0 radians to 2π radians. For a detailed discussion of the calculation of area moments, see Knoll & Stenson, (1968). (D)

6. Mean Straight Length. The mean of the distribution of the lengths of the straight segments in the perimeter. (M_s)

7. Variance of the Straight Lengths. The second moment of the distribution (about the mean straight length) of the lengths of the straight segments in the perimeter. (V_s)

8. Skewness of the Straight Lengths. The third moment of the distribution (about the mean straight length) of the lengths of the straight segments in the perimeter. (S_s)

9. Kurtosis of the Straight Lengths. The fourth moment of the distribution (about the mean straight length) of the lengths of the straight segments in the perimeter. (K_s)

10. Fifth Moment of the Straight Lengths. The fifth moment of the distribution (about the mean straight length) of the lengths of the straight segments in the perimenter. (H_s)

11. Variance of the Internal Angles. The second moment of the distribution (about the mean internal angle) of the magnitudes (in radians) of the internal angles formed by the perimeter. (V_g)

12. Skewness of the Internal Angles. The third moment of the distribution (about the mean internal angle) of the magnitudes (in radians) of the internal angles formed by the perimeter. (S_g)

13. Kurtosis of the Internal Angles. The fourth moment of the distribution (about the mean internal angle) of the magnitudes (in radians) of the internal angles formed by the perimeter. (K_g)

14. Fifth Moment of the Internal Angles. The fifth moment of the distribution (about the mean internal angle) of the magnitudes (in radians) of the internal angles formed by the perimeter. (H_g)

15. Area Variance, First Principal-Axis. The second moment of the area of the form along the first principal-axis. (μ_{20})

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1 A form is considered as a bivariate density function of unit height interior to and at the perimeter of the form. Moments of the bivariate density function are then considered moments of the area of the form.

16. Area Skewness, First Principal-Axis. The third moment of the area of the form along the first principal-axis. (μ_{30})

17. Area Kurtosis, First Principal-Axis. The fourth moment of the area of the form along the first principal-axis. (μ_{40})

18. Fifth Area Moment, First Principal-Axis. The fifth moment of the area of the form along the first principal-axis. (μ_{50})

19. Area Variance, Second Principal-Axis. The second moment of the area of the form along the second principal-axis. (μ_{02})

20. Area Skewness, Second Principal-Axis. The third moment of the area of the form along the second principal-axis. (μ_{03})

21. Area Kurtosis, Second Principal-Axis. The fourth moment of the area of the form along the second principal-axis. (μ_{04})

22. Fifth Area Moment, Second Principal-Axis. The fifth moment of the area of the form along the second principal-axis. (μ_{05})

PERCEPTION AND IDENTIFICATION OF SIMPLE IMAGES, PRESENTED IN DIFFERENT SEQUENCES, BY SUBJECTS SUBMITTED TO VARIOUS GRAVITATIONAL FIELDS

by

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SUMMARY

The present research was conducted on eleven normal, emmetropic subjects, known to be reliable. Whilst fixing the center of a perimeter with one eye they had to try to identify simple illuminated images, or at least to indicate the appearance of light. These simple images were located at 8°, 24°, 40°, 56° and 72° from the center, both on the right and left sides and were illuminated for a brief time either in regular succession or random order.

The subjects, submitted to gravitational fields of +1Gz, + I.8Gz and + 2.4Gz, did not show any appreciable change in their undefined perception power, or in their identification power of extra-foveal images, presented both in regular and random successions, as a consequence of different field intensity. The perception area of an undefined luminous message was distributed according to the well known shape of the monocular visual field. On the other hand, the area within which simple black and white images were identified was almost circular in shape and covered a surface which had a radius of about 20° centered on the fixation point.

The method used demonstrated only a slight difference between the results obtained when the images in the visual field were presented in a regular or random sequence.

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A. Scano G. Meineri R. Caporale

INTRODUCTION

Physiological problems related to the perception of single images, or theories of images, are in themselves very complex. Furthermore, since the fifties, they have become more and more complicated due to the influence of non ocular factors on visual phenomena. These factors, which have been ascertained from experimental evidence, are related to different sense organs and efferent impulses from the brain. During these same years, unusual or even completely new environmental conditions in aerospace flight have, in some instances, helped to clarify our ideas; more frequently, however, they have given rise to further difficulties.

It is well known that an aspect of the problem which has been most frequently investigated recently is the interaction between labyrinthine and other proprioceptive functions and vision. The practical importance of this, both in aerobatics and accident prevention, is so great as to deserve every effort to further our knowledge in this field. In particular, it is our opinion that the problem related to the power of reception and identification of images that fall on the retina at various distances from the fovea, has not received sufficient attention. It is well known that these images represent a more or less clear signal, toward which the eye then turns, to carry out an analytical examination.

Although well aware of the difficulties involved in this kind of psycho-physiological investigation, we scheduled a series of experiments concerning perception and identification. In the preliminary phase, simple graphic symbols were to be used and at a more advanced stage, numerals and dials, whose images would fall on different parts of the retina. The subjects were to be exposed to +1Gz, +1Gy, positive G higher than normal gravity and if possible, to weightlessness in parabolic flight. Our aims are: detection of the actual existence of "preferential directions" in perception, or functional prevalence of certain quadrants of the visual field, particularly in relation to the direction and intensity of the gravitational vector. Our programme foresees the determination of the limitations of image identification as a function of exposure time; interval between two successive stimuli; location of images in a monocular visual field and spatial succession of images, etc.

In this paper, the term "perception" is used in the conventional way to mean the reception of visual messages without a definite identification of the characters of these messages, whereas, "identification" indicates a clear recognition of these characters.

This first paper reports the results of a part of our programme and is limited to the preliminary experiments carried out so far, concerning different values of positive G.

EXPERIMENTAL METHOD

Experiments were conducted on 11 healthy emmetropic subjects, aged 21 to 45, (with the sole exception of one subject, affected by myopia: 3 diopters in both eyes). Bearing in mind the characteristics of our research, we selected our subjects from personnel in our laboratory, who were either experienced in human centrifuge experiments or in flight and endowed with satisfactory observation and critical powers. Directions relating to the required tasks were administered on a

Acknowledgement: We want to express our gratitude to Prof. L. Longhi, Institute Of Nervous and Mental Diseases, University of Rome, for his advice and specialist guidance, and the following Officers of the Italian Air Force Aerospace Medical Center, for their intelligent collaboration in setting up the experimental apparatus and in carrying on the experiments:
Ist Lt. V. Sorano, 2nd Lt. F. Lazzarini, 2nd Lt. N. Segatori and 2nd Lt. A. Romanin.

standardised basis before each experiment and absolute sincerity was recommended. The complete reliability of our subjects was ascertained in preliminary tests.

Our experimental apparatus consisted of a Foerster's perimeter designed for the study of the visual field, on which ten 0.20 watt neon lamps had been fixed at regular intervals. Each lamp was enclosed in an opaque tube (inner diameter 30 mm), open only toward the center of the perimeter (fig 1). Five lamps were located on each side of the perimeter namely, five on the temporal and five on the nasal side. The respective angular distances from the fixation center, on both sides, were 8°, 24°, 40°, 56° and 72°. The fixation center was marked by an almost pinhole luminous reddish spot obtained by means of a small lamp which was fixed in the very center of the graduated semi-circle of the perimeter. We did not place lamps at the farthest periphery of the visual field, since our preliminary tests had shown that their presence would hardly have been detected in our experimental conditions.

Small, transparent plexiglass discs were superimposed on the openings of the tubular lamp containers. Black silhouettes of the graphical or geometrical symbols - employed at each time - were applied on these discs (fig 2). The brilliance of the background of each spot against which the black images stood out, was about 0.13 lux, at the distance from which they were seen by the subject. The lamps, being without filament, had no latency. Lighting was controlled by a rotating switch, operated by a synchronous motor, connected to a precision rotation speed reducer (produced by the firm Jaquet). A special 'variac' was included in the instrument, so that lighting periods were regulated to 0.60 sec, and the interval between two successive lightings to 0.52 sec.

The values relating to the number of images, duration of stimuli and intervals, were adopted on an empirical basis for this preliminary stage of our research. This notwithstanding, we took into account Mackworth's investigations (1963) on immediate recall power of single images, and Bryden's researches (1968) on tachistoscopic presentation of shapes, numerals and letters. The succession of lightings could be reversed or changed at will, in order to make it irregular (for instance: 1-2-3...... 10, or 10-9-8.......2-1, or also 8-6-4-10-5-9-7-3-2-1). In the case of regular theories of images, both in clockwise and anti-clockwise sense, image number 1 was the most peripheral, and number 5 the most central in the left half of the visual field; while numbers 6 and 10 respectively indicated the most central and the most peripheral image on the right side. With regard to the angle of the graduated half-circle in respect to the horizontal line, the following 4 meridians were examined: horizontal (both in clockwise and anti-clockwise sense), inclined at 45° (in both senses), vertical (in both senses) and inclined at 135° (still in both senses).

Our attempts to record small unintentional eye movements during the experiments, using an electronystagmographic technique, had afforded such poor results that we decided to give up this kind of control. It was replaced, at +1Gz, by constant and direct observation. These subjects who were unable to keep their eyes practically still for the whole duration of an experiment were rejected. It has been planned to use infrared light cinematographic recordings for the objective control of eye stillness. The subjects had no previous knowledge either about the order in which the lights would be illuminated or the location of the 10 images, in any of the various experiments.

All experiments were carried out inside the gondola of our human centrifuge: in this way, the influence of different environments was prevented, since the experimental conditions were fairly uniform. The perimeter, with its chinrest, had been suitably fixed within the gondola which was illuminated by moderate and diffuse daylight.

By means of a microphone installed at the subject's side, he was able to report to the investigator the result of each lamp illumination, using a conventional verbal code. The subject was required to report whether he had only seen a light; an undetermined shape; or whether he had been able to identify the imagine positively. A tape-recorder was used to store this information.

The acceleration levels used were: +1Gz, +1.8G, +2.4Gz, with an average exposure time of about 6 min in each condition. We deemed it advisable not to surpass the latter value, in order to avoid untoward retinal or cerebral circulatory consequences of positive G; and so to allow the subjects to perform with their normal vigilance and visual acuity. It is our intention to test the

effects of higher positive G, as well as transverse G, in order to simulate more closely the conditions encountered in aerobatics.

EXPERIMENTAL RESULTS AND CONSIDERATIONS

The experimental results are reported in three tables and four diagrams. A fact which was to be expected, is confirmed in table I, namely, the definite difference between the capacity of perceiving a luminous spot of sufficient duration, and the capacity of identifying a shape, even if simple and perfectly defined. Table I shows that in each one of the three accelerative conditions, and with a regular naso-temporal succession of stimuli, 8 out of a total of 10 symbols were perceived, while only about half of the eight symbols were identified. It seems that there is a very slight decrease in the number of lights perceived, in relation to the increase of positive G. Such

TABLE I/ Mean values of the number of luminous messages perceived (b) and of images identified (i) by 8 subjects in the whole right eye visual field

Direction		$+1\ G_z$	$+1.8\ G_z$	$+2.4\ G_z$
→	b	8.5	8.6	8.4
	i	6.6	4.9	4.7
↑	b	8.4	7.9	7.7
	i	4.1	4.0	3.9
↘	b	8.6	8.5	8.5
	i	4.4	4.1	4.1

Note: Arrows indicate the sense of successive lamp lightings

a change, however, is very small, and the number of subjects is too limited to enable us to draw any conclusion. A second test (with temporo-nasal succession of lamp lighting) was administered to three subjects, immediately after the first one. Mean values for perception and identification were practically unchanged.

The subjects underwent oculogravic illusions, at the start, and in particular during centrifuge braking. In all cases the duration of illusory phenomena was very short and did not have any influence on the experiments.

Table II (concerning the same eight subjects) considers the four half-fields separately, i.e. nasal, temporal, superior and inferior. As far as light perception is concerned, the distribution of values reproduces in a similar way (but on a more restricted area) the shape of the white light

TABLE II: Mean values of the number of luminous messages perceived (b) and of images identified (i) with the right eye by 8 subjects in the two visual half-fields (left and right).

Direction		$+1\ G_z$		$+1.8\ G_z$		$+2.4\ G_z$	
		L	R	L	R	L	R
→	b	3.6	4.9	3.6	5.0	3.5	4.9
	i	2.2	2.1	2.5	2.4	2.4	2.4
↑	b	3.4	5.0	3.1	4.7	3.1	4.6
	i	2.0	2.1	2.0	2.0	2.0	1.9
↘	b	3.6	5.0	3.6	4.9	3.5	5.0
	i	2.0	2.4	2.1	2.0	2.0	2.1

Note: In vertical direction the right half corresponds to the frontal part

monocular visual field (fig 3), with its extension limited on the temporal side to the location of the most remote lamp (72°). On the other hand, values referring to symbol identification cover an almost circular but more restricted area, the radius of which is about 20° all around the center. In this latter case, individual differences are more evident. Some subjects, in each experiment, were only able to identify one image on the left and one on the right of the fixation point, while

other subjects could identify two images on the left, and two on the right. In any case the angle was more open than the angle corresponding to the projection of fovea centralis, which presumably does not exceed 10° on the whole. The round-shaped para-foveal area, within which images are identified, corresponds to a retinal area, in which cone concentration is still high, and, therefore, optical fibers are numerous.

It is worthwhile noting (table III, fig 3) that random presentation of stimuli does not seem to provoke important changes in perception of luminous messages and image identification in a gravitational field of +1 Gs. In a field of +2.4 Gs, however, the perception of luminous messages seems to be worse. The results reported in table III concern five different subjects, and give visual field values that are a little more restricted in regard to identification, if compared with table II. Such identification always took place for the two central images, and, in some cases, also for the two para-central images, even when they were included respectively among the first or the last, in the order of lighting. This observation would enable us to exclude the influence of mnemonic or distracting factors during the execution of the experiment.

TABLE III: Mean values of the number of luminous messages perceived (b) and of images identified (i) with the right eye in experiments following a regular succession (→); and in experiments following a random succession (|—|) in the two visual half-fields (left and right)

Direction		$+1\ G_z$ L	$+1\ G_z$ R	$+1.8G_z$ L	$+1.8G_z$ R	$+2.4\ G_z$ L	$+2.4\ G_z$ R
→	b	3.6	4.6	3.6	4.9	3.6	4.9
	i	1.6	1.8	2.0	1.8	1.6	1.6
|—|	b	4.1	4.9	3.6	4.9	3.4	4.6
	i	1.8	1.6	1.8	1.6	1.8	1.6
↗	b	3.6	4.1	3.4	4.1	3.4	4.1
	i	1.4	2.0	1.6	1.8	1.2	1.8
⟋	b	3.4	4.1	2.8	3.6	2.8	3.0
	i	1.6	1.6	1.6	1.4	1.8	1.4
↑	b	3.4	4.1	3.6	4.0	3.4	3.8
	i	1.6	1.6	1.6	1.6	1.4	1.2
I	b	3.9	3.2	3.0	2.8	2.8	2.8
	i	1.6	1.4	1.6	1.0	1.8	1.2

Note: In vertical direction the right half corresponds to the frontal part

Fig 4 affords a picture of the features of the identification field (upper part) and perception field (lower part) in a right handed subject, whose right eye was investigated. Fig 5 reports the same data, recorded in a left-handed subject, whose left eye was examined.

We think fig 6 is particularly significant. It concerns a subject submitted to stimuli (both in clockwise and anti-clockwise sense) in some experiments carried out in immediate succession. While image identification is apparently uninfluenced by the direction of the movement (in one case only does it seem to be influenced by the peculiar features of the symbol), the perception of luminous stimuli seems to be affected by a "dragging" effect, in the sense corresponding to the direction of the succession.

On the other hand, we were not able to observe an interesting phenomenon reported by Bryden et al (1968), consisting of a higher identification power concerning the images to the left of the fixation point, in the case of simultaneous, short lasting, presentation of a horizontal series of images. It can reasonably be presumed that, since our image presentation was not simultaneous, those conditions which cause a "perceptive preference" did not occur. Some subjects of ours reported that they perceived image number 7 as if it were thinner at its center, like a sand-glass.

We must point out that this image ought to re-enter, at least in part, in the area corresponding to the optical papilla.

SUMMARY AND CONCLUSION

Data obtained in this modest preliminary experimental series do not enable us to draw any generalised conclusions.

At present, we might only state that normal, emmetropic subjects submitted to gravitational fields of +1.0Gz, +1.8Gz and +2.4Gz do not show any appreciable change in their undefined perception power except for a slight reduction in a field of +2.4Gz, and in their identification power of extra-foveal images; presented both in regular and random successions, as a consequence of different field intensity. Following stimulation of moderate brilliance, and with exposure times and intervals close to half a second, as in our experimental conditions, the perception area of an undefined luminous message is distributed according to the well known shape of the monocular visual field. On the other hand, the area, within the boundaries of which simple black and white images are clearly identified, is almost circular in shape, and covers a surface, with a radius of about 20^{o}, centered at the fixation center itself.

The method used demonstrated only a slight difference between the results obtained when the images in the visual field were presented in a regular or random sequence.

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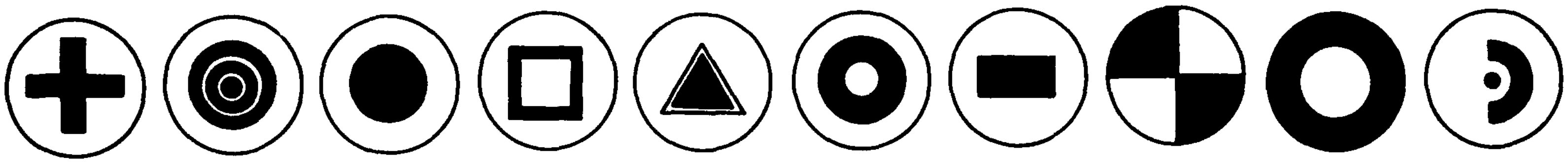
.Fig.2.

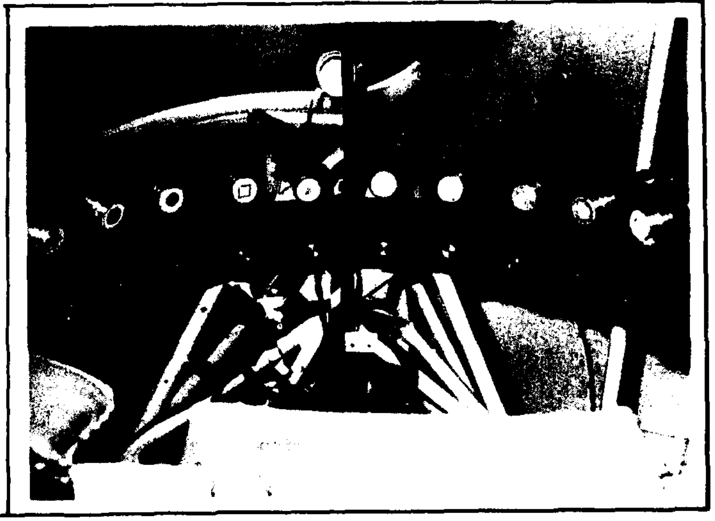
a)	1	2	3	4	5	6	7	8	9	10



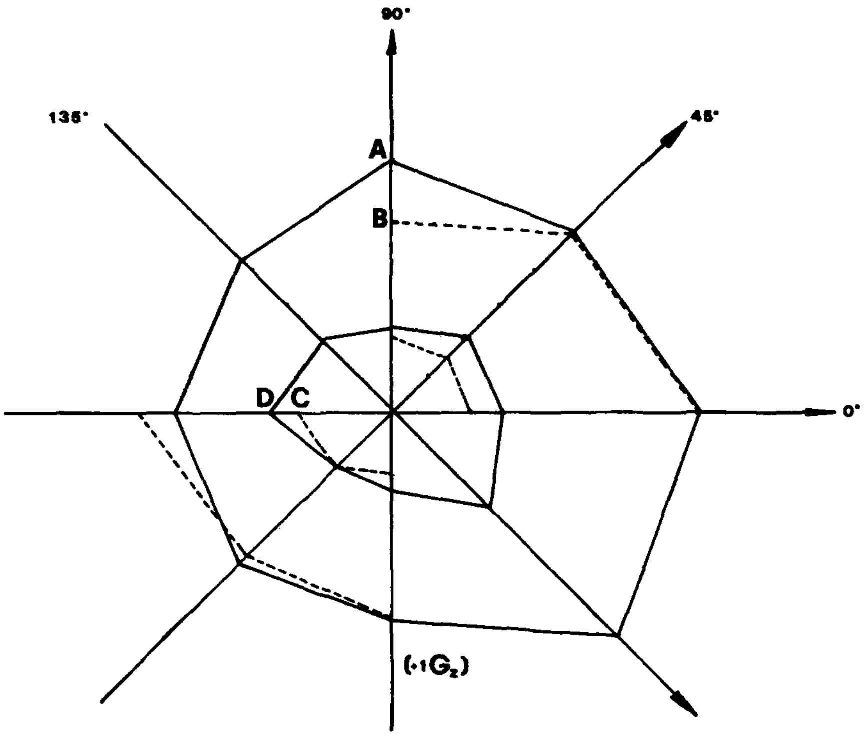
b)	10	9	8	3	5	2	7	1	6	4

a) regular sequence

b) random sequence



.Fig.1.



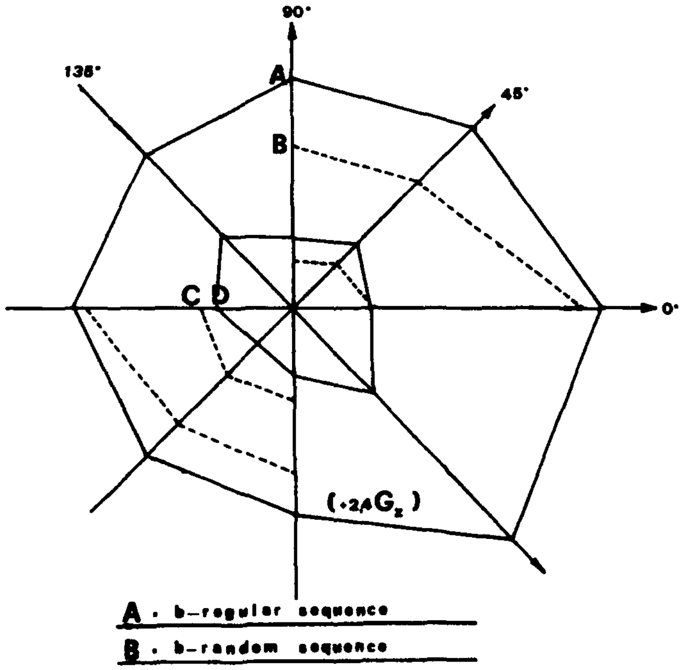
A- b- regular sequence

B- b- random sequence

C- i- random sequence

D- i- regular sequence

Fig.3a-



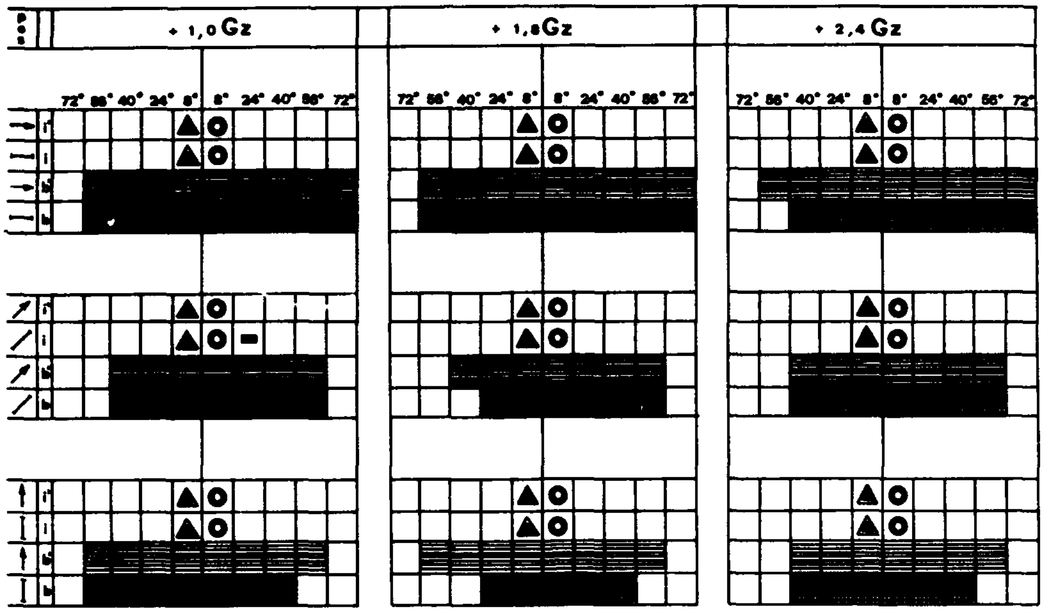
A - b-regular sequence

B - b-random sequence

C - i-random sequence

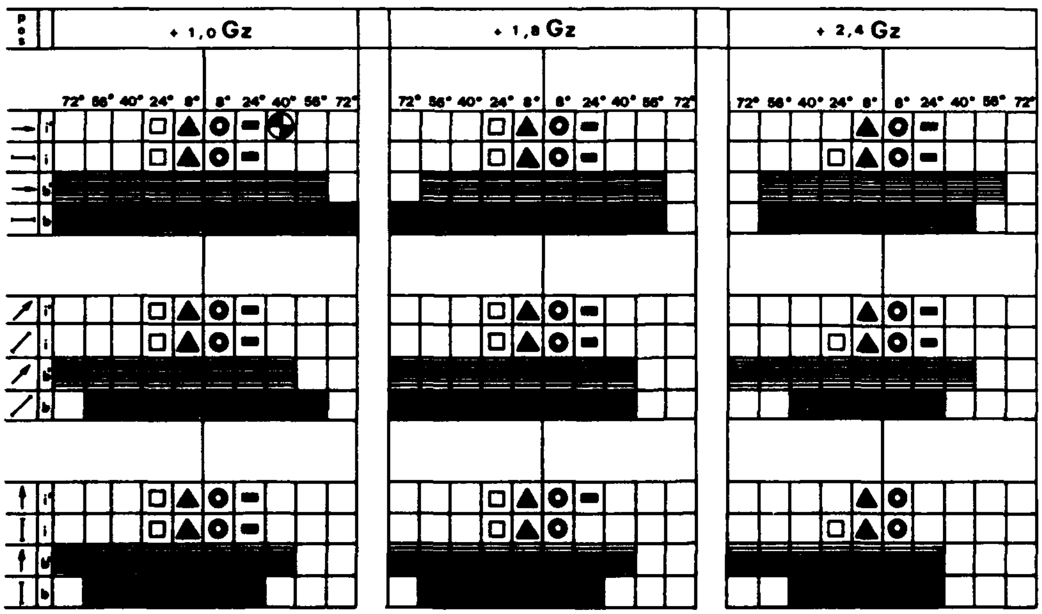
D - i-regular sequence

Fig.3b-



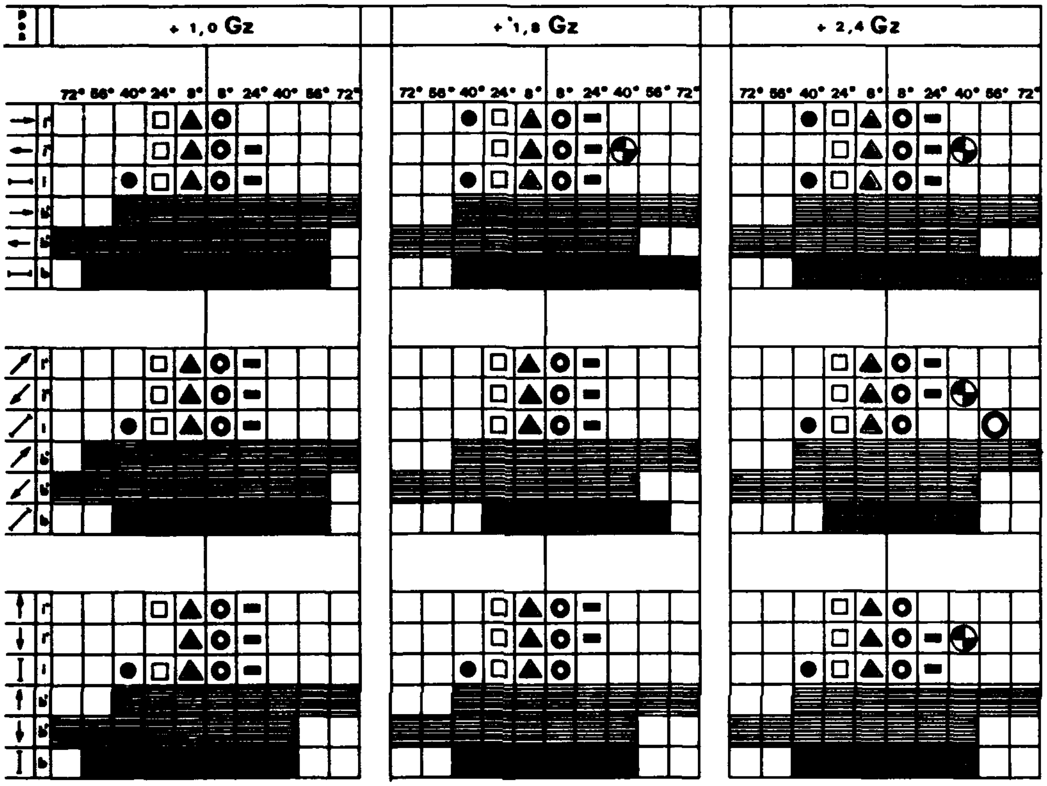
F.F.

Fig.4.



B.U.

Fig.5.



S.V.

Fig.6.

RETINAL ORGANISATION AND PATTERN RECOGNITION

by

M.L.Wolbarsht and H.G.Wagner

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Until recently cartography has been considered to be an art rather than a science, and for many years to come map making will continue to rely heavily on human skill, patience and accuracy. Although many of the procedures in map making could probably be automated it is unlikely that all the practical problems which this would entail can be solved in the near future. To those who specialise in what is called "Human Factors" or "Ergonomics" the design of some maps seems to violate certain basic principles for the presentation of information, by reducing the efficiency with which the maps can be used. The reasons for difficulties in using maps may relate to several factors. These include:

a) the information content of the map reflected in the level of detail which it presents;

b) the ways in which this information is presented, including coding, symbols, skill and relative prominence of types of information;

c) the conditions under which the map is to be used, such as a vibrating environment or at night;

d) the use to which the map is put and user opinions of its adequacy.

Many of these factors interact or should do so. For example, the information content of the maps may refer both to user opinion of what information is wanted and to task descriptions showing what information is essential.

To make a new map, especially if it is to achieve world wide coverage, is a vast and time consuming undertaking representing a very large number of man hours required for its preparation. Such effort cannot normally be justified unless the completed map will have a fairly large printing which implies that it may often have to serve several operational functions. In general, the more detail the map contains, the more it must fulfil many different functions rather than one only. Sometimes a map is intended to meet several requirements. An example of this is the recently introduced joint operations graphic, intended to meet certain needs of both tactical operations on the ground and strike and reconnaissance operations in the air, and to provide a means of liaison between them. This map, in seeking world wide coverage, has encountered the problem that any system of coding suitable for uninhabited or undeveloped regions becomes highly cluttered and almost unusable in regions of high population and development. Conversely an uncluttered appearance for developed regions may only be achieved by a featureless appearance for maps of undeveloped regions.

The purpose of the present paper is to approach the study of maps, and particularly of the joint operations graphic, by applying known human factors principles. This is done by considering a U.K. trial sheet on which user opinions have been obtained, by noting which features may cause difficulties in operational use and by suggesting the sort of changes on human factors grounds which could be proposed for consideration and evaluation.

JOINT OPERATIONS GRAPHIC - U.K. TRIAL SHEET.

A trial sheet of both "Air" and "Ground" versions of the joint operations graphic was produced for part of the United Kingdom and evaluated by informed user opinions, which were on the whole unfavourable. For many purposes the map was excessively cluttered and much information on it redundant, yet the users considered that much essential information was not shown. The version for ground use must incorporate sufficient detail to permit the specification of positions and the location of targets or strategic points with precision. This requires a detailed map, but the air version, expected to require less detail, actually has more information on it. The density of information is such that the aim of facilitating air and ground co-ordination has been compromised since there is no information which can be expected to stand out clearly on both map versions under all operational conditions, yet some information in this form would seem to be a prerequisite for easy and quick co-ordination. Basic information in co-ordination between air and ground operations should therefore stand out on both maps without searching since any information which does not appear boldly may be difficult to find under adverse conditions, such as darkness on the ground or a vibrating environment in the air, either of which might make fine detail difficult or impossible to read.

The requirements for knowledge of height differ greatly for land and air use. Although for certain flying tasks the pilot needs some information on its general nature, he is most concerned to know the highest points within given areas, and the points, their heights and the areas to which they refer should therefore all be clearly indicated. Although certain spot heights are given it is not easy to find them, to distinguish them from other elevations or to tell how far away the next spot height is. The extensive use of hill shading is in many ways misleading. Patches of hill shading in areas free from contour lines are difficult to interpret, steep sided valleys in a north-west to south-east direction are misrepresented by hill shading (as in south Wales) and the convention of shading as if the sun were in the north-west ensures that there can never be much visual correspondence between the shading and the appearance of the ground in the northern hemisphere.

The colour coding follows in many instances pictorial conventions, with the land levels increasing from a pale yellow through sandy brown tints to white, and blue and green being reserved for water and woodlands. This pictorial realism has been achieved at the cost of clarity. The succeeding changes of colour with increasing height do not themselves follow a logical progression and two height bands from 400 - 800 ft. and from 2,000 - 4,000 ft. are very similar in appearance. The colours used for roads are sufficiently similar to those for towns to obscure the road patterns within towns, and towns on the higher land do not stand out clearly. Although much detailed information on individual villages is given it is not easy to deduce the general shape of the villages although this might be a good guide to identifying them from the air. The emphasis on roads has established a pattern which could easily become obscure in all but flat and open country so that the detailed pattern information obtainable from roads may not in fact be of great value. Certain features which do stand out from the air such as disused railway lines have often been omitted and railways do not have the prominent appearance on the map which they often assume from the air. The convention of naming small villages is for many purposes self-defeating in areas where these are very numerous since occasions occur when names and villages are so close together that it is possible to assign the wrong name to a village.

APPLICATION OF HUMAN FACTORS PRINCIPLES.

When a map has been produced or is in its final stages of preparation it is too late to apply human factors principles in order to make substantial improvements. It is, however, possible to deduce certain of the major changes in the appearance of the map if these principles had been applied in time to be incorporated. The established principle of generally preferring colour to shape coding is already extensively incorporated in maps, though findings or reliable colour discriminations have not greatly influenced the choice of elevation tints.

For the world as a whole, most detailed information appears on low elevation land. This applies to roads, railways and rivers, to junctions between them, to towns, and to most information in verbal form. If numerous names are desired and the print size is small, these require good contrast. This suggests that the lightest tints on the entire map should be those representing low elevation land. This should therefore be nearly white and considerably lighter than that on the joint operations graphic. Increases in elevation should follow some logical scale of colour changes. If the scale of pale yellow to brown is employed each higher elevation should be both darker and more brown, so that it is possible to tell relative heights at a glance, and the confusion engendered by introducing a more sandy tint between two brown ones can be avoided. The major division between land and water should stand out and, therefore, a convention is needed which shows the shore line clearly by making the sea darker and by using colour. The areas of sea do not normally include greatly detailed information, and therefore they may be quite dark to retain good contrast with the land and words printed in a sea area may make up for poorer contrast by increased size since there is plenty of room for them.

Towns may occur at any land level and therefore must be represented by a convention which provides good contrast between the town and every elevation tint. If the shape of towns is important then it may be worth indicating them by outlining the shape, and by hatching in the town area rather than by having a uniform colour for the whole town. This might permit both a clearer representation of the town and some indication of elevation changes within it. The optimum colour for towns might depend on experimentation and on the lighting conditions under which the map would be used, but the use of grey striping or hatching, with a distinctive outline, might be worth trying. The positions of villages may need to be retained for ground use but for air use if a village is indicated it should be in terms of its general shape, and its detailed location with reference to a network of minor roads may be useless information for most air purposes. The clutter which this produces also would seem to prevent it from ever becoming an effective means of air/ground liaison and, therefore, the deletion of much detail of villages and roads from the air version would not appear to produce any major defects.

The road classification again suffers from lack of contrast with the towns and with some of the background elevation tints. A feature of roads which stands out for air and ground use is whether they are single or dual carriageway. Although these maps contain an elaborate road classification this is not obvious from a quick glance and does not become so even after detailed study. Dual carriageways, and particularly motorways, should stand out and it may be that some form of discontinuous or double colour, or hatch line, should be used to achieve this effect rather than retaining a single colour for all main roads. There seems no a. priori reason for not employing mixed colours to make a feature stand out.

Railways have long been considered to be a good navigation aid, and a feature on the landscape which should be shown clearly. The convention of black lines for railways has become well established and there seems no good reason for changing it providing a completely different convention is used for roads. Features of railways such as major cuttings and viaducts are major aids to navigation and should be shown. Disused railways often continue to be prominent features of the landscape and should therefore be shown, and when railways cross rivers and major roads these can provide good navigation references and such junctions should be clearly indicated, preferably with some coding to indicate which goes under which. A minor point is that it seems confusing that the symbol used for a station in the joint operations graphic is the same as that used for disused stations on ordnance survey maps. Although conventions may differ from one map to another it is unfortunate if the same convention represents different things on different maps.

It is uncertain how much information is lost if hill shading is removed altogether, and experimentation might be needed to study this problem. There are numerous instances where the current hill shading conventions however are misleading and, therefore, alternative methods of showing relief should be explored. A convention is needed which depends less on the geographical orientation of the main relief features and the present amalgamation of tints and contours has the effect of occasionally obscuring the information on how steep the slope is, since the presence of closely spaced contours may be obscured by the hill shading.

The pictorial conventions of blue for lakes and rivers and green for woodland are on the whole effective for major features, although the green changes in colour depending on the elevation tint on which it is superimposed. The convention works in areas of small woods, the shapes of which may aid navigation and confirm positions, but it is less successful in forested areas. The extent to which relatively minor streams should be indicated is not clear in terms of the various functions which the map must fulfil, and it may be that some experimentation would be necessary to establish the value of presenting small rivers and the extent to which bridges on them should be emphasised. There may, for many navigation purposes, be a good case for introducing a convention denoting the type of bridge. Generally, lakes stand out well because they contrast with all other colours used in the map.

It has been noted that the map is in many ways excessively detailed, particularly in terms of roads and place names. There are, however, several landscape features which occur relatively rarely but should be included because they are a major aid to navigation when they do occur, and could aid air/ground liaison. Such features include factory chimneys, church steeples and very large buildings of a distinctive character which are not in towns. Other identifiable features such as lighthouses could be shown much more prominently.

Although it is possible to work from first principles, and suggest what should be included and what excluded from maps, and the codings and conventions which would be most effective, such suggestions should not be accepted without detailed consideration of the environmental conditions under which the maps must be used. The main problem in ground use of maps is probably to ensure that they will remain satisfactory at night when they must be used under conditions of light illumination which may itself be coloured. In the air it is possible that the map may be used with red environmental lighting, although the problems which arise from this are not thought to be particularly serious. A further problem is the degradation of the information because of vibration in the aircraft, and the print size for lettering should be chosen with this problem in mind. Some work has been done on the choice of fonts for maximum legibility in printed words, although this has often emphasised legibility rather than readability. A further question is whether the font should be designed to permit the inclusion of as many names as possible in the minimum space which allows them to be read under good conditions, or whether it should be designed rather to reduce search times for finding the place names. In the joint operations graphic there may be considerable difficulty in locating place names from grid references, partly because these references do not stand out well, this being in turn a function of their contrast with the background and the spacing between them. The inclusion of numerous place names suggests that they may be used to specify positions rather than grid lines on the map, although the latter would normally be more accurate if a system were adopted allowing reasonably accurate interpolation.

CONCLUSIONS.

It is emphasised that the exercise of applying human factors principles to the design of maps and charts is meant to suggest the formats on which opinions should be obtained and evaluations conducted. It is not suggested that the results of applying these principles can be accepted without verification. This exercise of working from first principles is not a replacement for other sources of information, but an addition to them. It remains essential to establish by task analysis and task description what information is required for each operational role, to obtain user opinion, and to show not only that the map is acceptable but that it constitutes an improvement.

The main outcome of applying these principles would be to make the map lighter and much less cluttered, and to delete some information and introduce certain symbols which at the moment are not present and generally indicate major aids to navigation. Colour codings would follow more logical principles, but not necessarily pictorial ones, and a small amount of very important information would stand out very clearly to form a basis for liaison, and to emphasise those features considered most important for the operational roles for which the map is intended. This might be achieved, if necessary, by abandoning the principle of a uniform single colour for each type of feature, and by introducing, for example, hatching instead of a single colour to show towns or distinctive roads. It would seem essential to obtain in some detail the opinions of the users of maps when trial sheets are made and to conduct comparative trials to ensure that new maps are better than those which they are intended to replace. It may also be worth considering the abandonment of uniform world-wide principles which lead to cluttered maps for some areas and nearly blank maps for others, and to put on the maps the information needed to fulfil the operational roles over each particular type of terrain. Thorough job analysis would suggest how seriously this alternative should be studied.

L'INFLUENCE DE L'ECLAIRAGE POUR LA LECTURE DES CARTES DE NAVIGATION

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Une enquête a été effectuée sur 163 navigants tant de l'aviation militaire que de l'aviation civile, en tenant compte surtout de l'opinion des navigateurs plus spécialement chargés de la lecture des cartes.

Il leur a été demandé, selon le type d'avion utilisé, quel mode d'éclairage ils préféraient pendant la période de roulage, le décollage, le vol de croisière et lors des procédures d'atterrissage. Ils devaient aussi donner leur avis sur les intensités d'éclairage mises à leur disposition, sur les perturbations de leur adaptation rétinienne, la fatigue éprouvée du fait de la lecture des cartes et le pourcentage de lumière blanche et rouge en cas d'utilisation d'un mélange des deux couleurs.

Aux conclusions tirées de cette enquête a été ajouté le cas particulier du pilote de monoplace de chasse pouvant évoluer à basse altitude et à grande vitesse.

L'utilisation des cartes de navigation et des plans de vol est nécessaire à toutes les phases d'un vol de nuit, aussi bien au décollage qu'à l'atterrissage, pour connaître la disposition des pistes et les procédures d'approche, qu'au cours même de la mission afin de permettre la vérification des points de repère terrestres et l'identification d'objectifs au sol.

Dans tous ces cas, il importe de conserver une bonne adaptation rétinienne permettant la vision extérieure aux faibles brillances nocturnes et d'éviter l'éblouissement que produirait une lumière vive facilitant la lecture des cartes.

Pour connaître l'opinion de ceux qui sont le plus habituellement chargés de la lecture des cartes, une enquête a été entreprise au cours du second trimestre 1968 auprès de 163 navigateurs tant civils que militaires.

Il leur a été demandé, selon le type d'avion utilisé, quel mode d'éclairage ils préféraient pendant la période de roulage, le décollage, le vol de croisière et lors des procédures d'atterrissage. Ils devaient aussi donner leur avis sur les intensités d'éclairage mises à leur disposition, sur les perturbations de leur adaptation rétinienne, la fatigue éprouvée du fait de la lecture des cartes et le pourcentage de lumière blanche et rouge en cas d'utilisation d'un mélange des deux couleurs.

Les cartes mises à leur disposition, qu'il s'agisse de militaires ou de civils étaient celles actuellement en service et qui sont de deux types : français ou américain.

Nous avons enfin envisagé le cas particulier du pilote de monoplace de chasse pouvant évoluer à basse altitude et à grande vitesse.

Nous allons examiner successivement les résultats de l'enquête concernant les navigateurs militaires, nous verrons ensuite l'opinion des navigateurs civils.

A. NAVIGATEURS MILITAIRES

Les 45 questionnaires exploités concernaient :

22 navigants chasse
15 navigants transport
8 navigants n'ayant pas précisé le type d'avion utilisé.
Cette dernière catégorie a été retenue comme référence avec les deux autres catégories.

Les moyennes d'âge dans chaque catégorie sont comparables :

31 ans pour le groupe chasse
33 ans pour le groupe transport
36 ans pour le troisième groupe.

Le nombre d'heures de vol était respectivement de :

56.827 pour le groupe de chasse, dont 4.079 heures de nuit
69.260 pour le groupe de transport, dont 10.000 heures de nuit
25.400 pour le dernier groupe, dont 4.270 heures de nuit.

Voyons maintenant les réponses aux différentes questions posées :

1) MODE D'ECLAIRAGE PREFERE

a) Phase de roulage

MODE D'ECLAIRAGE	CHASSE	TRANSPORT	3ème CATEGORIE
ROUGE	4 sujets	2 sujets	4 sujets
	18,1 %	13,3 %	50 %
U.V.	1 sujet	2 sujets	2 sujets
	4,5 %	13,3 %	25 %
ASSOCIATION	15 sujets	11 sujets	2 sujets
	68,1 %	73,3 %	25 %
PAS D'AVIS	2 sujets		
	9,09 %		

Un éclairage associé semble préféré par la majorité des navigants.

b) Phase de décollage

MODE D'ECLAIRAGE	CHASSE	TRANSPORT	3ème CATEGORIE
ROUGE	2 sujets	2 sujets	2 sujets
	9,09 %	13,3 %	25 %
U.V.	5 sujets	3 sujets	3 sujets
	22,7 %	20 %	37,5 %
ASSOCIATION	13 sujets	10 sujets	3 sujets
	59,09 %	66,6 %	37,5 %
PAS D'AVIS	2 sujets		
	9,09 %		

L'éclairage associé prédomine encore mais on note une augmentation significative des utilisateurs d'U.V. dans le groupe chasse.

c) Phase de croisière

MODE D'ECLAIRAGE	CHASSE	TRANSPORT	3ème CATEGORIE
ROUGE	1 sujet		2 sujets
	4,5 %		25 %
U.V.	6 sujets	6 sujets	3 sujets
	27,2 %	40 %	37,5 %
ASSOCIATION	13 sujets	9 sujets	3 sujets
	59,09 %	60 %	37,5 %
PAS D'AVIS	2 sujets		
	9,09 %		

Dans cette phase où la navigation nécessite l'utilisation maxima des cartes, on remarque l'abandon de l'éclairage rouge sur les avions de transport et sa nette désaffection sur les avions de chasse.

L'association reste préférée, mais les utilisateurs d'U.V. sont en nette augmentation, surtout sur les avions de transport.

d) Phase des procédures d'atterrissage

MODE D'ECLAIRAGE	CHASSE	TRANSPORT	3ème CATEGORIE
ROUGE	5 sujets	2 sujets	2 sujets
	22,7 %	13,3 %	25 %
U.V.	6 sujets	4 sujets	2 sujets
	27,2 %	26,6 %	25 %
ASSOCIATION	9 sujets	9 sujets	4 sujets
	40,9 %	60 %	50 %
PAS D'AVIS	2 sujets		
	9,09 %		

Le rouge recommence à être utilisé davantage, au détriment de l'U.V.

2) GAMME D'INTENSITE MISE A LA DISPOSITION DES NAVIGANTS

INTENSITE	CHASSE	TRANSPORT	3ème CATEGORIE
INSUFFISANTE	2 sujets		
	9,09 %		
SUFFISANTE	19 sujets	14 sujets	8 sujets
	86,3 %	93,4 %	100 %
TROP ELEVEE		1 sujet	
		6,6 %	
PAS D'AVIS	1 sujet		
	4,5 %		

Seuls les chasseurs montrent une légère restriction. Tous les autres l'estiment suffisante.

3) DESADAPTATION POUR LA VISION EXTERIEURE

DESADAPTATION	CHASSE	TRANSPORT	3ème CATEGORIE
PLUS MARQUEE	3 sujets	3 sujets	2 sujets
AVEC LE ROUGE	13,6 %	20 %	25 %
PLUS MARQUEE	18 sujets	11 sujets	5 sujets
AVEC L' U. V.	81,8 %	73,3 %	62,5 %
PAS D'AVIS	1 sujet	1 sujet	1 sujet
	4,5 %	6,6 %	12,5 %

En ce qui concerne la désadaptation pour la vision extérieure, on constate que la majorité des navigants est plus désadaptée par un éclairage autre que le rouge.

4) FATIGUE RESULTANT DE LA LECTURE DES CARTES

FATIGUE	CHASSE	TRANSPORT	3ème CATEGORIE
AVEC LE ROUGE	12 sujets	9 sujets	6 sujets
	54,5 %	60 %	75 %
AVEC L' U.V.	7 sujets	5 sujets	2 sujets
	31,8 %	33,3 %	25 %
PAS D'AVIS	3 sujets	1 sujet	
	13,6 %	6,6 %	

La lecture des cartes sous un éclairage rouge fatigue la majorité des sujets avec un pourcentage qui croît parallèlement à l'augmentation de l'âge, du fait de la difficulté de mise au point sur le foyer rouge.

5) POURCENTAGE DE LUMIERE BLANCHE ET ROUGE UTILISE EN CAS DE MELANGE

40 % des navigants du groupe transport utilisent 80 % de rouge et 20 % des sujets 70 % seulement. Les autres n'utilisent qu'un pourcentage inférieur à 50 %. Pas de majorité significative dans le groupe chasse, mais trois options paraissent préférentielles : 70 %, 50 % et 30 % de rouge.

Dans la troisième catégorie, tous les navigants déclarent employer 60 % et plus de rouge.

6) CHOIX DES CARTES

Deux sortes de cartes sont actuellement mises à la disposition des navigants : cartes françaises ou américaines.

CARTES	CHASSE	TRANSPORT	3ème CATEGORIE
TYPE FRANÇAIS	16 sujets	5 sujets	6 sujets
	72,7 %	33,3 %	75 %
TYPE U. S.	3 sujets	5 sujets	
	13,6 %	33,3 %	
LES DEUX TYPES	2 sujets	3 sujets	1 sujet
	9,09 %	20 %	12,5 %
PAS D'AVIS	1 sujet	2 sujets	1 sujet
	4,5 %	13 %	12,5 %

L'aviation de chasse préfère les cartes françaises, l'aviation de transport emploie à égalité les deux types de cartes.

7) CAS DU PILOTE DE MONOPLACE POUVANT VOLER A BASSE ALTITUDE ET A GRANDE VITESSE

Si, sur les avions militaires multiplaces, la majorité des navigateurs préfère augmenter l'intensité d'éclairage de la cabine pendant une courte phase, afin de consulter la carte -et ceci d'autant plus volontiers que l'avion se trouve en dehors d'une période critique du vol-, au moment de l'atterrissage et pendant le quart d'heure qui le précède, c'est l'éclairage dit "de secours", c'est à dire la lampe de poche qui est la plus souvent utilisée.

Le pilote de monoplace de chasse est placé dans des conditions très différentes, il doit à la fois assumer la conduite de l'appareil, la vision à l'extérieur du cockpit et la lecture des cartes placées sur ses genoux. Il a été vérifié qu'étant donné sa position dans l'espace restreint dont il dispose, l'éclairage du tableau de bord ne permet pas de consulter efficacement une carte quels que soient le mode d'éclairage et le taux d'illumination utilisés. Seul reste possible l'emploi du projecteur orientable placé à gauche et à la hauteur de la tête du pilote et que ce dernier peut faire descendre au niveau de la carte. Ce projecteur, qui revient automatiquement en place après usage, peut éclairer en blanc ou en rouge. Le blanc reste en pratique le seul utilisé. Il faut reconnaître que, lors d'un vol à grande vitesse et surtout s'il est pratiqué à basse altitude, la majorité des pilotes français renonce à la perte de temps que provoque la saisie du projecteur et son orientation sur la carte. Ils préfèrent utiliser la lampe de poche placée sur la cuisse de leur combinaison de vol et dont ils peuvent filtrer la lumière entre leurs doigts pour éclairer rapidement le point précis de la carte qu'ils doivent examiner pour vérifier leur position.

B. NAVIGATEURS CIVILS

Les 118 questionnaires exploités concernaient :

42 navigants sur CARAVELLE
30 navigants sur BOEING 707
10 navigants sur D.C. 8
20 navigants sur avions divers (D.C. 4 - D.C. 6 - VISCOUNT etc ...)
16 navigants n'ayant pas précisé le type d'avion utilisé

Dans chaque catégorie, les moyennes d'âge varient respectivement de 38 ans à 42 ans, la moyenne la plus basse étant celle des utilisateurs de CARAVELLE S.E. 210 et la plus élevée celle des utilisateurs de BOEING 707.

Le nombre d'heures de vol était respectivement de :

396.937 sur CARAVELLE soit une moyenne de 9.680 dont 4.345 heures de vol de nuit.
354.998 sur BOEING (moyenne 12.241) dont 4.019 heures de vol de nuit.
97.245 sur D.C. 8 (moyenne 9.724) dont 3.322 heures de vol de nuit.
Pour les deux dernières catégories, les moyennes d'heures étaient respectivement de 6.178 et 9.487 dont 1.736 et 3.420 heures de vol de nuit.

1) MODE D'ECLAIRAGE PREFERE

a) Phase de roulage

MODE D'ECLAIRAGE		CARAVELLE	BOEING	D.C. 8	TYPES VARIES	TYPE NON PRECISE
ROUGE		2 sujets	5 sujets	1 sujet	5 sujets	1 sujet
		4,7 %	16,6 %	10 %	25 %	6,25 %
BLANC		7 sujets	4 sujets	4 sujets	2 sujets	3 sujets
		16,6 %	13,3 %	40 %	10 %	18,75 %
ASSOCIATION		32 sujets	20 sujets	5 sujets	13 sujets	12 sujets
		76,1 %	66,6 %	50 %	65 %	75 %
PAS D'AVIS		1 sujet	1 sujet			
		2,3 %	3,3 %			

La majorité des navigants préfère un éclairage associé.

b) Phase de décollage

MODE D'ECLAIRAGE		CARAVELLE	BOEING	D.C. 8	TYPES VARIES	TYPE NON PRECISE
ROUGE		3 sujets	7 sujets	1 sujet	4 sujets	4 sujets
		7,1 %	23,3 %	10 %	20 %	25 %
BLANC		1 sujet	1 sujet	4 sujets	4 sujets	
		2,3 %	3,3 %	40 %	20 %	
ASSOCIATION		35 sujets	19 sujets	5 sujets	12 sujets	12 sujets
		83,3 %	63,3 %	50 %	60 %	75 %
PAS D'AVIS		3 sujets	3 sujets			
		7,1 %	10 %			

L'éclairage associé a la préférence dans des proportions sensiblement égales à celles de la période de roulage.

c) Phase de croisière

MODE D'ECLAIRAGE	CARAVELLE	BOEING	D.C. 8	TYPES VARIES	TYPE NON PRECISE
ROUGE	1 sujet	3 sujets		2 sujets	1 sujet
	2,3 %	10 %		10 %	6,25 %
BLANC	18 sujets	12 sujets	6 sujets	6 sujets	5 sujets
	42,8 %	40 %	60 %	30 %	31,25 %
ASSOCIATION	23 sujets	15 sujets	4 sujets	12 sujets	10 sujets
	54,7 %	50 %	40 %	60 %	62,50 %

Le blanc l'emporte sur le rouge et l'éclairage associé. Sur D.C. 8 il est nettement le plus employé.

d) Phase des procédures d'atterrissage

MODE D'ECLAIRAGE	CARAVELLE	BOEING	D.C. 8	TYPES VARIES	TYPE NON PRECISE
ROUGE	4 sujets	6 sujets	1 sujet	6 sujets	5 sujets
	9,5 %	20 %	10 %	30 %	31,25 %
BLANC	3 sujets	2 sujets	4 sujets	4 sujets	
	7,1 %	6,6 %	40 %	20 %	
ASSOCIATION	35 sujets	21 sujets	5 sujets	10 sujets	11 sujets
	83,3 %	70 %	50 %	50 %	68,75 %
PAS D'AVIS		1 sujet			
		3,3 %			

Le pourcentage d'utilisateurs de rouge ou d'associé augmente en cette période délicate du vol.

2) GAMME D'INTENSITE MISE A LA DISPOSITION DES NAVIGANTS

INTENSITE	CARAVELLE	BOEING	D.C. 8	TYPES VARIES	TYPE NON PRECISE
INSUFFISANTE	4 sujets	4 sujets			2 sujets
	9,5 %	13,3 %			12,25 %
SUFFISANTE	37 sujets	24 sujets	10 sujets	19 sujets	14 sujets
	88 %	80 %	100 %	95 %	87,5 %
TROP ELEVEE	1 sujet	1 sujet			
	2,3 %	3,3 %			
PAS D'AVIS		1 sujet		1 sujet	
		3,3 %		5 %	

La très grande majorité des navigants estime suffisante la gamme d'intensité mise à leur disposition (de 80 à 100 %) selon les types d'avions. C'est dans le groupe des navigants sur BOEING (où sont les sujets les plus âgés) que le pourcentage des insatisfaits est le plus important.

3) DESADAPTATION POUR LA VISION EXTERIEURE

DESADAPTATION	CARAVELLE	BOEING	D.C. 8	TYPES VARIES	TYPE NON PRECISE
PLUS MARQUEE AVEC LE ROUGE	6 sujets	3 sujets	5 sujets	5 sujets	7 sujets
	14,2 %	10 %	50 %	25 %	43,75 %
PLUS MARQUEE AVEC LE BLANC	33 sujets	23 sujets	3 sujets	13 sujets	8 sujets
	78,5 %	76,6 %	30 %	65 %	50 %
PAS D'AVIS	3 sujets	4 sujets	2 sujets	2 sujets	1 sujet
	7,1 %	13,3 %	20 %	10 %	6,25 %

Les navigants sont plus désadaptés par un éclairage blanc dans leur majorité (50 à 78,5 %). Seule la catégorie DC 8 donne des résultats différents, sans doute du fait de l'emploi plus fréquent de la lumière blanche à toutes les phases du vol.

4) FATIGUE RESULTANT DE LA LECTURE DES CARTES

FATIGUE	CARAVELLE	BOEING	D.C. 8	TYPES VARIES	TYPE NON PRECISE
AVEC LE ROUGE	30 sujets	24 sujets	9 sujets	14 sujets	12 sujets
	71,4 %	80 %	90 %	70 %	75 %
AVEC LE BLANC	8 sujets	2 sujets	1 sujet	3 sujets	4 sujets
	19 %	6,6 %	10 %	15 %	25 %
PAS D'AVIS	4 sujets	4 sujets		3 sujets	
	9,5 %	13,3 %		15 %	

La lecture sous éclairage rouge est la plus fatigante (70 à 90 % des sujets). Ce sont les plus jeunes (âge moyen 38 ans) sur CARAVELLE et avions de types divers qui se plaignent le moins de la fatigue due au rouge. Et, contrairement à ce qui eût été prévisible, ce ne sont pas les sujets les plus âgés qui s'en plaignaient le plus.

5) POURCENTAGE DE LUMIERE BLANCHE ET ROUGE UTILISE EN CAS DE MELANGE

Là aussi, ce sont les navigants sur D.C. 8 qui utilisent des mélanges où le rouge ne dépasse pas 50 % tandis que la majorité des navigants des autres catégories emploie des associations où le rouge prédomine.

6) CHOIX DES CARTES

CARTES	CARAVELLE	BOEING	D.C. 8	TYPES VARIES	TYPE NON PRECISE
TYPE FRANÇAIS	17 sujets	8 sujets	5 sujets	2 sujets	9 sujets
	40,4 %	26,6 %	50 %	10 %	56,25 %
TYPE U.S.	5 sujets	4 sujets	1 sujet	5 sujets	
	11,8 %	13,3 %	10 %	25 %	
LES DEUX TYPES		5 sujets		1 sujet	
		16,6 %		5 %	
PAS D'AVIS	20 sujets	13 sujets	4 sujets	12 sujets	7 sujets
	47,1 %	43,3 %	40 %	60 %	43,75 %

Bien que l'absence d'avis exprimé soit ici le plus important, on constate que ce sont les cartes françaises qui emportent le plus de suffrages.

De l'enquête dont nous venons d'examiner les résultats, il semble que l'on puisse dégager les conclusions suivantes :

1° La grande majorité des navigants utilise un éclairage associé au cours des différentes phases du vol.

2° C'est pendant le vol de croisière que l'éclairage blanc est le plus employé, aussi bien chez les militaires que chez les civils et quel que soit le type d'appareil.

3° La gamme d'intensité paraît suffisante à la grande majorité des navigants (86 à 100 % pour les militaires, 80 à 100 % pour les civils).

4° L'éclairage blanc est, de l'avis général, celui qui désadapte le plus (62,5 à 82 % pour les militaires, 50 à 78,5 % pour les civils). Il est à noter que, chez les militaires, le blanc désadapte d'autant plus que les sujets sont plus jeunes. Chez les civils on ne retrouve pas le même parallélisme. C'est cependant le groupe le plus jeune (celui de CARAVELLE) qui présente le plus fort pourcentage.

5° La lecture des cartes sous éclairage rouge fatigue plus que sous éclairage blanc. Les militaires signalent cette fatigue dans 54,5 % à 75 % des cas, les pourcentages augmentant parallèlement à la moyenne d'âge. Chez les civils, les pourcentages sont comparables (70 à 90 %) et l'on note que ce sont les plus jeunes qui se plaignent le moins de l'éclairage rouge.

6° Il n'a pas été possible de déduire de cette enquête une tendance en ce qui concerne le choix du pourcentage de rouge dans les associations de couleurs. Les résultats des différents groupes montrent des variations et une grande répartition des choix.

7° Les cartes françaises sont utilisées presque exclusivement dans l'aviation de chasse. Le transport militaire emploie à égalité cartes françaises et américaines. Les navigants civils semblent se prononcer également pour les cartes françaises.

8° Pour les pilotes de monoplace pouvant voler à basse altitude et à grande vitesse, c'est l'emploi de la lampe de poche qui est considéré comme le moyen le plus rapide et le plus efficace pour consulter une carte.

L'intérêt de cette enquête est donc d'avoir montré l'accord des navigants sur le problème de la lecture des cartes en fonction de l'éclairage.

Cet accord nous paraît avoir d'autant plus de valeur que nous nous sommes adressés à deux types de population utilisant des appareils de tous modèles et accomplissant des missions très variées.

PHILOSOPHIES OF VOICE COMMUNICATION SYSTEMS DESIGN

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SUMMARY

There is a need for improved aircraft voice communication systems in the armed services, FAA and NASA applications. Recorded samples show the urgent need for improvement.

It is proposed that the philosophy of systems design that has evolved since World War II is largely responsible for the present low efficient systems. The popular assumptions held by design engineers about distortion, bandwidth conservation and intelligibility criteria explain some of the impedances to the successful development of ideal systems.

As a solution to the problem, a new philosophy of communication systems design is proposed. Data from recent experiments support the argument that the realization of improved voice communication systems will depend largely upon a change of philosophy. Tape recordings of new experimental systems are presented as evidence that it is possible to have high intelligibility under high ambient noise conditions. A basis for changing criteria for accepted speech intelligibility is presented.

DUE TO LACK of a better one, we have chosen to call the title of this presentation: "Philosophies of Voice Communication Systems Design." In this regard, many electronic engineers are of the opinion that any degree of intelligibility is adequate for Government work. This is not a solitary position. Some acoustic and auditory scientists, e.g. at FAA, share this position which is unacceptable to us.

The Navy has concurred with our position on an individual basis and in a more public way, as represented in a formal report, "Effective Life Support Helmets", published by Biotechnology Inc. and supported by the U. S. Navy.

To define the problem, we will present recordings of three present systems as a demonstration of the effects of distortion. The first is a system in a private aircraft in which you will hear a fatal crash. We were asked to identify the voice of the speaker as male or female. Your guess is as good as ours. The second recording is a tape of the GEMINI 10 space-ground communication between Astronaut Young and NASA Houston and narrated by NBC. The third is a recording of the system in a CH-47 (Chinook) Army Helicopter, using the conventional system and followed by a recording of our experimental system.

TAPE RECORDINGS

FAA TAPE RECORDING. The first recording is a collection of excerpts from a tape of communications between a civilian aircraft and a radar control station.

NASA TAPE RECORDING. Everyone would probably agree that civilian aircraft and FAA communications are not too sophisticated, however, the efforts expended to provide the best possible for Astronauts are well known. Here is a sample of recorded communications on a docking flight between Astronaut Young and the ground. The NBC narrator employs a linear system and represents a product of the philosophy that we are recommending. In contrast, you can hear the military type system that can easily be identified as either the NASA ground station or the spacecraft. The military sound or quality is due to distortion.

CHINOOK TAPE RECORDING (With Distortion). After repeated communications to establish contact with another ship, it was finally made. The transmitting ship repeated the message - that is the test phrase.

CHINOOK TAPE RECORDING (Without Distortion). Next, we will present a recording which was made in one of the same Chinooks with our experimental linear system.

C-54 TAPE RECORDING. The last sample is an excerpt from a tape recorded by the U. S. Naval School of Aviation Medicine, Pensacola, Florida, a few years ago. It is a transmission from a C-54 to the Acoustic Laboratory at Pensacola.

The primary differences between the first three taped samples of speech and the last two lie in the amount of system distortion. Of the various types of distortions, peak-clipping is perhaps the most controversial. It is a type of amplitude distortion that is used for limiting dynamic range which many assume improves intelligibility under high noise conditions. The following experimental data are presented as a refutation of the premise that peak-clipping is beneficial to speech intelligibility.

Figure 1 shows the masking contour of listeners who heard a 450 Hz tone with and without peak-clipping. The interference of the extra harmonic effects is reflected in the contour derived from data collected under the clipping conditions. Each point on the contours is a mean of three listener responses. These results show the effects of extra useless energy on perception and may be expected to mask critical low amplitude consonant sound with negatively sloped noises. Also, it shows how the ear is subjected to unnecessary noise by this process.

Figure 2 shows the results obtained from listeners after listening to a recording of a speaker in various noise levels, when the recording was subject to 20 db of peak-clipping. These data clearly indicate a loss of intelligibility.

In conclusion, we have shown that high intelligibility is possible in high noise levels. We can get 90% in 120 db noise. It is therefore recommended that it be a requirement to design future equipment with linear characteristics. We believe that a high quality system would have furnished valuable information about the NASA disaster. We also believe that such systems will improve the efficiency and reduce cost of military operations.

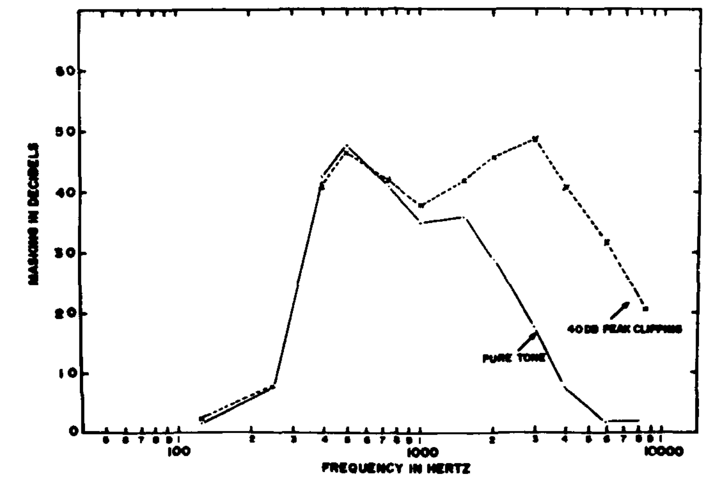

Figure 1. Masking Effects of a Pure and Peak Clipped 450 Hz Tone at 85 DB SPL Mean Values Derived from Responses of Three Listeners.

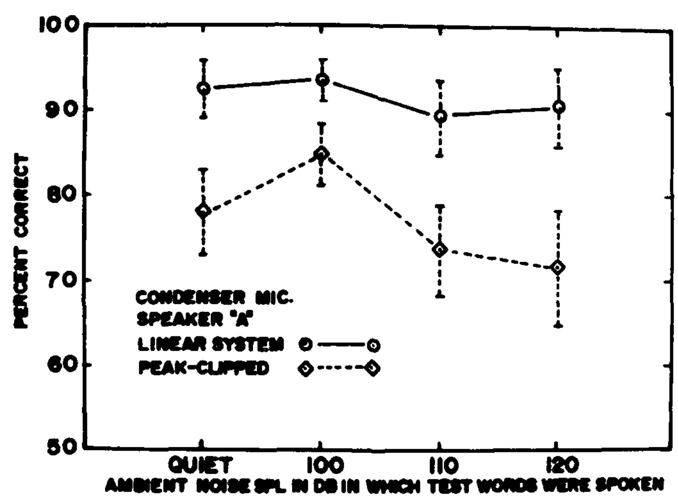

Figure 2. Effect of 20 DB Peak-Clipping and a Band-Pass of 200-6000 Hz on Listeners' Reception Scores.

RESEARCH FINDINGS ON TARGET DETECTION THAT HAVE IMPLICATIONS FOR PATTERN RECOGNITION

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SUMMARY

A series of studies at Wright-Patterson Air Force Base have examined the target-finding behavior of observers. A variety of sensors and displays have been used with static and moving scenes. Some of the numerous findings having implications for pattern recognition are discussed. It is pointed out that the detection-recognition dichotomy may be misleading; that, within wide limits, contrast may influence reaction time more than it does probability of detection; that either context or briefing may relegate resolution and contrast to minor roles; that target finding is complicated by target-background interaction; that likely target locations reduce image quality requirements while unlikely ones increase them. It follows that a priori search patterns can be inefficient, and that detection or recognition prediction models must be very complex to be useful. Finally, the antagonistic demands upon observer behavior of different performance goals are discussed.

INTEREST AND EXPERIMENTATION in pattern recognition is about as old as experimental psychology, although the expression has become popular only recently. Much, though by no means all, of the older research was done with geometrical figures and other simplified stimulus material for which precise control and specification of image characteristics could be obtained.

Although much progress in understanding pattern vision was obtained with such material, for example, see Hake (1957), by the late 1950's it became apparent that the results of the classical pattern vision studies, including those that had used real scenes, left much to be desired. They offered almost no help in predicting the performance of test subjects in observing either the real world or pictures of it. It was clear that powerful variables were present that were not even hinted at in the available literature. Those who were working with real world problems in perception, performance, or the evaluation of systems utilizing human observers were forced to take the plunge and commence their own experimentation with real scenes or representations of them in the form of pictures or other displays. This was particularly true of many military psychologists.

For this reason, the author and his co-workers have been doing research on the target detection behavior of human observers involved in simulated target-finding systems, as exemplified by rapid reconnaissance aircraft. Some of their investigations have utilized moving images on a display and some have involved static pictures. The variables investigated have included scene and target complexity (a mixture of many variables), scene illumination, image resolution, display format, image motion rate, image polarity, target intelligence (briefing), task load, number of allowed target choices, and number and types of sensors. Aerial and motion picture cameras, passive infrared sensors, side-looking radar, and the unaided eye have been used as sensors. The test subjects have included college students, United States Air Force Strategic Air Command and Tactical Air Command bombardier navigators, and photo interpreters.

In each study the subjects were required to search for objects of types specified by the instructions as being military targets. Subjects were trained to find and recognize images that were or could represent targets. Since, in many of the studies, subjects were looking for targets whose location, exact appearance, or existence were unknown or uncertain, a major part of their task involved pattern recognition. Careful observation of test behavior, use of an eye-movement camera in some of the work, post-test interrogation, and data analysis led to numerous findings that have implications for target recognition.

The present paper will not focus upon and review specific reports, for they were not directly aimed at pattern recognition. Also, many of the findings particularly relevant to pattern recognition were not covered in the reports and/or were incidental findings. Also, several investigations are still in the publication process. However, all results are from studies either done by, directed by, or advised by the author. Although countless others have done similar work having numerous implications for pattern recognition, the scope of the present document prohibits discussing their findings.

IMPLICATIONS FOR PATTERN RECOGNITION

From post-experimental interrogation of test subjects and from the experience of the author and his co-workers in the preparation and study of the stimulus material, it is clear that detection and recognition often, in the awareness of the observer, are simultaneous and inseparable events. In such cases, one does not first become aware that some object or portion of an image is a target then realize what type of target is represented. However, in some cases this sequence does consciously occur. Since an observer cannot be aware of some of his own information processing activity, it does not follow from the above that detection and recognition are sometimes not a two-step process. The important point is that it may be foolhardy to assume that the conventional breakdown of behavior into detection, recognition, and identification stages or phases always represents, in the organism, separable or distinguishable steps.

In some studies in which target contrast was decreased, within limits, detection time increased. However, when viewing time limits were not short, there was often little or no effect on the probability of detection. Partly because of contextual cues, changes in image resolution sometimes had similar effects. One study (Rhodes, 1964) demonstrated that target size, picture sharpness and contrast, picture detail, logical restrictions on possible target location, target shape and pattern, target location and target isolation were all determinants in the target finding behavior of test subjects. In this study, observers were shown a cutout of the target but did not know where it would appear in the scene. In another somewhat similar study (Nygaard, et al, 1964) that used artifically embedded real targets, target-background interactions were significant: the difficulty of finding targets depended on both the target pattern and the background pattern. A target that is easy to find in one scene may be difficult in another while the reverse may be true of another target in these same scenes.

New complications appear when briefing material accurately portrays both the appearance and location of targets on a display or in a scene. In this case, almost all subjects found almost all targets. In fact, even targets that did not appear on the display, even as a smudge or blob, were by operational definitions, consistently, accurately, and quickly located, detected, and recognized. In studies with such precise and detailed briefing material, image scale, image resolution and contrast, display size, etc. have been varied with little or no variation in the performance of the observer. In such cases, it cannot be claimed that a pattern in the scene was recognized. The point is that when some knowledge of the specific target is available, the

usual minimum requirements for image quality will not always be pertinent. Here, little, if any, of the variation in subject performance may be attributable to whatever it is that the experimenter is varying.

Expectation can have further effects. Thus, objects in unlikely, though genuine, locations in static or dynamic scenes were often difficult to find or went undetected even though the displayed target signature, by itself, was more than adequate for almost instant recognition. Thus, an airfield closely surrounded by hills in a scene containing mostly flat land was not easily found: observers often concentrated on the flatland, ignoring the hills.

In a similar vein, in moving image displays with target-available-times of up to a minute or more, high contrast well defined targets were often missed due to concentration of search upon what appeared to be a "richer" terrain, in this case a city.

In all of these cases, context was very important. In a related manner, it was found that automobiles on roads, men on roads or standing near autos were easily recognizable despite image patterns (target signatures) that were inadequately resolved in detail to permit recognition out of context, i.e., at other locations in the scene. In a word, context can make otherwise unrecognizable patterns readily recognizable. One may conclude that, in some cases, required image resolution and contrast is that which is adequate for the appropriate contextual cues.

Since context is so important, forcing subjects to utilize any systematic search pattern prearranged without taking into account scene characteristics will be inefficient when total allowed viewing time is short. If searchers can avoid such an arbitrary pattern and take advantage of the "lay of the land," they will do so.

Another finding, and one not new to psychology, was that vehicles in motion relative to their background were often readily found and recognized, despite target signatures that, in terms of resolved image detail, were completely inadequate when not moving. Also, for example, it was found that an elongated upright featureless "blob" moving away from a house was immediately seen and recognized as a man. Here, motion, context, and pattern were all important.

In several of our studies, nontargets were frequently mistaken for real targets. Sometimes they even outnumbered real targets. Examination of the images of these spurious targets revealed that many really did look like targets: it was not imagination and invention on the part of the observers. The false positives were drastically reduced in number by limiting the number of allowed target choices, or by counting only those responses for which subjects expressed high confidence, or by providing observers with a priori target intelligence (briefing).

In several studies by our group in which small scale images (radar) were used, image motion on the display was varied to simulate aircraft speeds of from a few hundred knots to thousands of knots. Image motion rate at the highest simulated speeds, due to the small scale of the images, allowed several seconds of viewing time for all areas of the terrain. Usually the decrease in percentage of targets detected was negligible to very small in going from the slowest to the fastest speeds, even for unbriefed targets. However, there was usually a large decrease in the number of false positives.

With stationary scenes, a similar effect was found: with increasing viewing time the number of new targets detected per unit of time decreased more rapidly than did the number of false positives. Another study (Bate, et al, 1967) had results that also were consistent with little or no improvement in performance with increase in viewing time. This study, using moving scenes, allowed subjects to stop image motion temporarily, but this was found not to improve observer performance.

The point being made is that under some circumstances a decrease in the time allowed to examine a scene for certain patterns may have no harmful effect on pattern recognition performance, and may even improve it.

This result draws attention to a problem which represents a dilemma. The pattern recognition or target detection performance of an observer can be measured by the percentage of targets detected (completeness), the percentage of the reported detections that represent real targets (accuracy), or the average time to detect targets (detection time). A high score or rating on any one criterion can usually be obtained only at the expense of low scores on other criterion measures. Thus, often to find most of the targets, many objects that do not look much like targets must be designated as targets, thereby making many mistakes and obtaining a low accuracy score. One must also take an appreciable time to study the scene, thereby obtaining a long (poor) average detection time per target. Hence, it is necessary to take into account more than one performance measure and to assign importance or "weight" by the significance of each for reaching specific goals. Often, in real systems, several contradictory performance requirements make compromises or trade-offs necessary.

SUMMATION

1. The analysis of observing behavior into separate stages of detection and recognition is probably, in many cases, misleading if one infers that it always happens this way.

2. Within limits, reduced contrast of target images may increase detection time with little or

no effect on probability of detection. Because of use of cues from the image context, this sometimes applies to resolution.

3. There are strong target-background interactions so that difficulty of detection varies not only with the nature of the target pattern and the nature of the background, but also with relationships between them.

4. When briefing is thorough and accurate, targets that do not appear on the display or in the scene are quickly found and reported.

5. In real scenes, "obvious" targets in unlikely locations or in areas containing few targets are frequently not seen: search is concentrated on more likely or "richer" terrain.

6. With highly likely locations, objects poorly resolved and of low contrast are often easily recognized.

7. Men or vehicles in motion are often readily found and recognized despite target signatures that would be inadequate were they not moving.

8. Systematic a priori search patterns used when search time is limited and terrain is nonuniform may be very inefficient.

9. False positives pose a serious problem in some situations and the several methods that were tried, while drastically reducing their number, did so at a cost in percentage of targets detected.

10. Although decreased viewing time or increased rate of image motion may impair performance, it does not always do so, and accuracy can improve with less available time.

11. Accuracy, completeness and reaction time are often all important measures of performance, yet the type of behavior required to do well on any one of them often lowers performance on the others.

CONCLUSIONS

The use of real world stimulus material has uncovered and allowed examination of numerous variables that influence pattern recognition. Some were expected, some probably not. In any case, it is apparent that finding objects and patterns in the environment via either direct visual examination or by the use of a system of sensor, display and observer is an extremely complex enterprise. Context, target motion, target and background characteristics and their interaction, target location in a scene, relationship of search pattern to the location of objects in the scene, etc. All play important roles in observer performance. Thus, predicting observer performance is extremely difficult. This means that the many current target recognition and/or detection models now in vogue that include only resolution, target size and contrast, average eye fixation time and a few other simple conventional variables cannot avoid being exercises in futility.

When and if more adequate models are devised, we will still have the problems associated with a multiplicity of observer performance measures that impose contradictory restraints upon the behavior of the observer.

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** Dr. H. C. Self was the technical monitor on this research.

The research reported in this paper was conducted by personnel of the Aerospace Medical Research Laboratories, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. This paper has been identified by Aerospace Medical Research Laboratories as AMRL-TR-68-156. Further reproduction is authorized to satisfy needs of the U. S. Government.

AIRCREW PROTECTIVE SYSTEMS

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SUMMARY

This paper covers the development of armor materials, especially reinforced plastic-ceramic composite armor, for protection of men and equipment against small arms fire and shell fragments. Emphasis is placed on the application of these materials to aircraft, particularly rotary wing aircraft. Each armor component is identified and the production of the woven-roving glass fabric laminate and its assembly into the composite is described.

Since the main purpose of body armor is to reduce casualties, the basic scope of a battle casualty survey is discussed and the results of wound ballistic studies are reported. The psychological effects of the use of body armor in combat are also described.

Illustrations of current applications of armor for helicopter crewmen and helicopter components in Southeast Asia are shown.

ANY PROJECTILE CAN be defeated by providing an adequate thickness of armor material. But this adequate thickness, in most cases, materially increases the weight which must be carried by the human being or the mechanical device being protected. This creates a very real addition to the human energy or mechanical horsepower which is required to obtain desired mobility. Thus, reduction in weight without corresponding loss in protection is the driving force behind all armor development programs.

DEVELOPMENT OF PLASTIC-CERAMIC COMPOSITE ARMOR

The modern history of lightweight composite armor had its beginning in 1945 when experiments were conducted with plate glass placed in front of and in contact with Doron, the U.S. Army's name for a newly developed reinforced plastic armor effective against fragments from grenades and mortar shells. The resulting combination was capable of stopping caliber .30 rifle bullets and weighed much less than conventional steel armor. From 1955 on, the U.S. Army Laboratories sought to apply such composite techniques to produce lightweight armor vests for the infantry soldier for protection against munitions fragments. Although reinforced plastic-ceramic composites were also studied at the time, their effective weight exceeded the maximum allowable weight for infantry application.

The year 1963, when Goodyear Tire and Rubber Company obtained their patents on Hard Faced Ceramics, marked the beginning of a new era in composite armor for protection against small arms fire. Through improved ceramic processing techniques, the required armor weight was considerably reduced and the development of these composite armor materials is still progressing in the direction of lower weight. The war in Southeast Asia, with the extensive use of helicopters, focused attention on armor for the protection of helicopters and their crews subjected to small arms fire from the ground. In 1964, there was developed the first practical composite armor for providing protection against caliber .30 armor-piercing projectiles at close range. This armor consisted of an aluminum oxide ceramic material as the front component and a Doron back component. Its worth in Southeast Asia was quickly shown in providing aircrew armor, armor for pilot seats, and as protection for vulnerable aircraft components in U.S. Army aircraft.

The component elements of this plastic-ceramic composite armor are indicated diagrammatically in Figure 1. From left to right, facing the projectile, are the spall shield or cover, the spall shield adhesive, the ceramic facing of the composite, the composite adhesive, and the reinforced plastic backing.

Spall shields for aircrew armor consist of a ballistic type nylon fabric cemented to the ceramic. The function of these spall shields is to localize the damage to the ceramic armor component and to retain the ceramic and projectile fragments generated by the impact in order to minimize the possibility of injury to the arms, legs or face of the wearer or nearby personnel and of damage to nearby equipment. The ceramic facing may be of aluminum oxide, silicon carbide or boron carbide. Originally, the reinforced plastic used was Doron, a low resin content laminate made with woven-glass cloth having a starch finish in an unsaturated polyester-styrene resin. At the present time, a 23 to 24 oz/sq yd (approximately 8 centigrams per sq cm) starch-oil or gelatinous sized glass woven-roving fabric is used because it provides more effective armor and is also less expensive.

A limited quantity of composite armor has been made with an aluminum alloy for the backing plate instead of the reinforced plastic and all armored seats for the UH-1 (Huey, Iroquois) and CH-54 (Sikorsky, Sky Crane) are of this configuration.

The adhesive for bonding together the ceramic and the reinforced plastic components is either a two-part solventless polyether-polyurethane or polysulfide, or a more complex interlayer bonding system of a polyurethane on the ceramic and an epoxy on the nylon fabric spall shield.

The typical damage produced by bullet impact on ceramic-plastic armor is illustrated with aircrew armor torso shields in Figure 2. The damage is reasonably localized. The inner circle, from which the ceramic is completely gone, is about 1 inch in diameter. The outer circle of fractured but still adherent ceramic is about 4 inches in diameter. Individual cracks may extend beyond this localized area depending on many factors, including armor size, shape, and impact location. The reinforced plastic backing material may be undamaged, bulged or delaminated depending upon the severity of the ballistic impact.

FABRICATION OF PLASTIC-CERAMIC COMPOSITE

The main operations required in producing this composite armor are:

1. Production of the ceramic facing.
2. Production of the reinforced plastic backing.
3. Bonding of the backing to the facing (these last two operations may be performed simultaneously).
4. Bonding the spall shield to the facing and, if required, bonding a rubber-type edging to the entire armor assembly.
5. Assembling the composite armor plate into the fabric garment for crewman wear or attaching the plate to the aircraft.

The ceramic facing is produced by a variety of processes depending upon its composition. Aluminum oxide and silicon carbide facings are made by cold-pressing finely ground powder and then sintering. Boron carbide facings are either first cold-pressed, then hot-pressed or they can be hot-pressed directly from powder. These facings are made in curved shapes for aircrew armor to conform to body contours, as shown in Figure 3.

For larger armor, required to protect vital aircraft components, flat and curved tiles are made and assembled to arrive at the final desired configuration.

The woven-roven glass fabric used for making the reinforced plastic backing material weighs about 24 ounces per square yard (approximately 8 centigrams per sq cm) and has a starch-oil finish. For armor purposes, the laminate must be capable of delaminating over a relatively large area centralized around the point of projectile impact. Adhesion between the glass and the resin matrix must be minimal but still adequate to withstand low-velocity mechanical (as opposed to ballistic) damage. For this reason, resin content is maintained at levels much lower than the usual glass reinforced plastic. Resin content is about 25% by weight of the reinforced plastic, and the specific gravity of the laminate is about 2.0.

The bonding resin is an unsaturated polyester with not more than 30% styrene. Versions now coming into use substitute diallyl phthalate for a portion of the styrene. The laminate is rated as self-extinguishing, which means that it will not support combustion in the absence of flame from another source.

The glass reinforced plastic backing can be made by three methods: (1) matched metal die molding, (2) autoclave molding, and (3) a combined one-step molding and bonding method in an autoclave. Matched metal die molding uses either a wet-layup or a pre-preg process. Typical molding conditions are a mold temperature of 250 to 300°F (120 to 150°C) depending upon the resin utilized, molding pressure of 160 lbs/sq inch (11.25 kg/sq cm) and molding time of twenty minutes. The autoclave method uses the following procedure: a vacuum bag for either wet or dry layup and then autoclaving under a pressure of 100 psi (7.03 kg/sq cm) at an autoclave temperature of 300°F (149°C) for thirty minutes. A ceramic facing lined with a separator or coated with a release agent is used as the mold. The <u>combined</u> molding-and-bonding method is similar except that the ceramic face is coated with the bonding medium, and no separator is required. The bonding medium consists of an epoxy film adhesive on a nylon fabric carrier with or without a polyurethane coating on the ceramic. The woven-roving glass reinforced plastic ply next to the bonding medium is dry ply and sometimes has an epoxy finish rather than the starch-oil finish. The combined method is gradually superseding the separate molding and bonding procedures, not only because of the savings in cost and time, but also because of better quality control.

In the two-step method, the reinforced plastic backing must have its bonding surface sanded in addition to any edge finishing that may be necessary. The polysulfide or polyurethane adhesive is next applied and the facing and backing parts are placed together. Ideal mating and bonding of the two parts is seldom achieved; voids and poorly bonded areas are often present and the adhesive thickness may be 0.030 inch or even greater. On the other hand, the one-step process yields a uniformly bonded product with a very thin adhesive layer (in the order of 0.005 inch). A picture of this reinforced plastic backing is shown in Figure 4. The finished armor is either sewn into a fabric garment so that it can be worn by the aircrewmen, or is installed in the aircraft or attached to the vulnerable aircraft component it is to shield.

PHYSIOLOGICAL AND PSYCHOLOGICAL ASPECTS OF BODY ARMOR

In the assessment of any type of armor, it is necessary to consider the system which the armor is designed to protect. In the case of body armor, the system is of course the human body. For many years the United States has conducted studies of battlefield casualties.

The basic objective of all battlefield casualty studies is to analyze the effect of firearms and their projectiles upon human tissue. Modern warfare has become so versatile and changes in weapons have been so rapid that for military purposes a study of this nature must be conducted continuously, not only in every theater of combat operations, but also in the laboratory, using experimental animals. These studies must extend in range from simple missile laceration to the complicated effects of atomic weapons explosions and must cover the period from the first medical care in a battalion aid station to the point of maximum recovery in a general hospital. As each new weapon appears, its wounding properties must be carefully evaluated. This involves close liaison with ordnance; identification of new weapons and missiles; knowledge of velocities, size, shape and mass of missiles; percentage incidence of various missiles; and the percentage to which a given body region is involved. This is in addition to the proper classification of wounds. These studies must also evaluate the method, time, and distance of patient evacuation in relation to primary wound treatment, wound contamination, and all the other variables of wound repair.

A field wound ballistics study ideally includes a continuous study of the wound from the time of occurrence until the time of maximum repair followed by a study of the functional effects of that repair and the various adaptation phenomena. Therefore, such a study demands the cooperation and coordination of a vertical segment of medical personnel indoctrinated in this continuity of wound evaluation so that sample-type wounds will receive standardized observations and photographic recordings at critical intervals throughout the period of medical evacuation and hospitalization.

The following are examples of criteria formulated by a typical survey team and are a natural part of any battle casualty survey investigation:

1. Regional frequency of wounds, that is, number of times a particular region of the body is involved in the total number of cases studied.
2. Weapon and missile identification for each wound.
3. Type of wound, distribution and frequency.
4. The effect of wound contamination and secondary infection.

Wound ballistic studies, in most instances including photographs and X-rays, were made on soldiers from all of the United States divisions in frontline action in the Korean conflict. Some of these soldiers were wearing armor vests made of twelve plies of basket weave nylon weighing thirteen ounces per square yard. The layers of nylon were triangularly spot bonded together and covered with vinyl-coated nylon fabric to make the complete vest. The purpose of these studies was to assess the efficiency of this type of body armor.

Table I shows the distribution of wounds inflicted on casualties who were <u>not</u> wearing the protective vest, and Table II shows the distribution of wounds inflicted on casualties who <u>were</u> equipped with the felted nylon vests. Note that the percentage of head wounds and neck wounds is almost exactly the same in both cases, but that the chest wound percentages dropped from 11.3 percent to 4.7 percent, and the percentage of wounds in the upper part of the back dropped from 7.5 percent to 4.0 percent. Similarly, abdominal wounds were reduced from 4.1 percent to 1.6 percent.

Remember that these studies were made merely on all-nylon vests and not on the plastic-ceramic composite armor vests. As yet there have been insufficient studies to obtain statistically meaningful results with the composite vests, but limited experience indicates considerable improvements over the all-nylon vests, as would be expected.

Medical research on the use of body armor would be incomplete without a consideration and understanding of the psychological effects on the soldier wearing the armor. Some of the most important factors to be considered are motivation, the effect on confidence, the effect on aggressiveness, the effect on morale, and finally the acceptance by the soldier.

The use of body armor is motivated by one of the more powerful impulses in our psychological makeup, i.e., the desire to survive. In the heat of actual combat, soldiers have later reported that they rarely notice the weight and bulkiness of the armor vests. In these tense periods it seems that the psychological desire for protection outweighs the physiological deficit resulting from the added burden. On the other hand, interviews with soldiers returning from patrols which had no fire fights or skirmishes with the enemy, indicate that the men are less disposed to wearing body armor and are more critical of its weight and limitation of mobility.

The effect of body armor on confidence is probably best expressed in the results of the post-use interviews where over 85% of the men stated that they felt safer and more confident when

wearing armor. This feeling of increased safety and assurance is undoubtedly of paramount importance in explaining the widespread acceptability of body armor in combat, particularly in the case of helicopter crewmen.

Interviews with commanders, who have led troops wearing body armor in combat, have repeatedly emphasized that aggressiveness is increased and that there is more of a desire and willingness to engage the enemy at close quarters. Since one of the great deterrents to aggressiveness in combat is fear of being wounded or killed, it would seem that the feeling of increased safety and confidence, in part at least, accounts for the increased aggressiveness noted by the troop commanders.

A poll of front line physicians and surgeons resulted in the almost unanimous expression of opinion that the use of body armor results in an increase in morale among combat troops. The measurement of morale is difficult and varies with many factors which cannot be kept constant while other unknown factors are being tested. It is rational to conjecture, however, that the morale of troops would be elevated as long as they possessed an item which would diminish their chances of being wounded or killed.

Under certain conditions, the effect of body armor on morale may not be good. For example, during the last month of a recent test period there were several instances where helicopter crewmen who had previously used body armor expressed a reluctance to their flight commanders to go on flights when body armor was not available. These instances were precipitated by the fact that there were not enough vests to go around or that the items had been moved to other sectors or units for more favorable testing. In any situation where crewmen had previously used body armor and for some reason it became limited in supply or not available, the effect on morale was definitely unfavorable. This limitation in supply has now been overcome so that all crewmen are now provided with armored protection.

APPLICATIONS OF PLASTIC-CERAMIC COMPOSITE ARMOR

Two kinds of helicopter-armor applications now in use in Vietnam will be described:

1. Personnel armor worn by the individual aircrewman.
2. Pilot seats and also panels installed on aircraft interior walls and flooring for the protection of personnel.

Personnel armor for pilots and copilots consists of front and back torso shields although the back shield is not worn if the seat back is armored. Door gunners also wear this armor. This type of armor is shown in Figure 5.

All aircrewmen operating in Vietnam in aircraft subject to small arms fire from the ground, are now equipped with such armor, which was adopted as standard equipment on 25 January 1968. All armor worn by aircrew personnel has a quick-release feature so that it may be instantly jettisoned in an emergency.

Specially designed armored seats are now in use in helicopters such as the UH-1 (Huey, Iroquois), the CH-54 (Sikorsky, Sky Crane), the AH-56 (Cheyenne) and the AH-1G (Cobra). Armor panel inserts are used on the CH-47 (Chinook), the OH-13 (Bell, Sioux), the OH-23 (Hiller, Raven) and the OH-6A (Hughes, Cayuse) as well as on certain fixed-wing reconnaissance aircraft. Most of the armored seats use plastic-ceramic composite armor added to the seat itself or to nearby bulkheads and aircraft structures or to both. Examples of this type of installation are shown in the next series of illustrations.

The first one, Figure 6, shows back and side armor constructed of three plastic-ceramic composite panels fastened together. The fourth panel (lower part of picture) for the underside of the seat is steel armor.

Figure 7 shows this armor installed in the OH-6A (Hughes, Cayuse) aircraft.

Figure 8 is of flat plate composite armor installed under the seat cushions of the OH-13 (Bell, Sioux) aircraft.

Figure 9 shows composite armor added to the seats of the CH-47 (Chinook). The armor includes back and bottom panels as well as panels on the sides. A headguard is attached to the outboard side of each seat.

The UH-1 (Huey, Iroquois) seat shown in Figure 10 was the first of this type and was first delivered in 1965. Protection is provided from the bottom, back and sides.

Figure 11 shows an integrated armor seat for the AH-1G (Cobra). This differs from the UH-1 (Huey, Iroquois) seat in that the armor is both the seat and the load bearing structure rather than a seat hung on a metal supporting frame. The back and bottom are one piece and the two side panels are attached.

The seat, as shown in Figure 12 is supported with aluminum pads. The seat can withstand a crash load condition of 18 g's for the combined weight of the seat and occupant.

The next group of illustrations show armor installations for U.S. Air Force aircraft.

The first one, Figure 13 shows armor locations on the C-130 cargo aircraft. Ten armored seats, most with floor and side armor, are indicated. The armor systems fabricated on the first procurement for C-130 aircraft, represent the greatest quantity yet made under one contract. Two hundred ten thousand (210,000) pounds of reinforced plastic were used.

Figure 14 shows the pilot's, copilot's, and flight engineer's seat and the top part of the navigator's seat.

Figure 15 shows one of these seats with seat cushions, and Figure 16 with seat cushions removed, gives you a better picture of the armor components.

Figure 17 shows a cargo-master's seat, and Figure 18 is a picture of armor for flare boxes. This armor is designed not to stop a projectile completely but to reduce their energy sufficiently to prevent the flares from being activated.

Figures 19 and 20 show armor for protection of the fuel control system on the OH-6A (Hughes, Cayuse) helicopter.

The armor on the older aircraft operating in Vietnam has been installed as a retrofit, but the new models, such as the AH-1G (Cobra) and the AH-56 (Cheyenne) had integral armor systems as part of their configuration throughout concept formulation.

Work on producing lighter, more effective armor for protection of aircrews and aircraft is a continuing effort which we cannot afford to diminish.

Table I. REGIONAL DISTRIBUTION OF 1,474 WOUNDS IN 908 WIA CASUALTIES NOT WEARING BODY ARMOR

Body Region	Number of Wounds	Percent of Total Wounds
Head	208	14 1
Neck	48	3.2
Chest	167	11 3
Back		
Upper Part	111	7 5
Lower Part	103	7 0
Abdomen	60	4 1
Extremity.		
Upper	359	24 4
Lower	408	27.7
Genitalia	10	0 7
TOTAL	1,474	100.0

Table II. REGIONAL DISTRIBUTION OF 850 WOUNDS IN 552 WIA CASUALTIES WEARING BODY ARMOR

Body Region	Number of Wounds	Percent of Total Wounds
Head	121	14 2
Neck	23	2 7
Chest	40	4 7
Back		
Upper Part	34	4 0
Lower Part	78	9 2
Abdomen	14	1 6
Extremity.		
Upper	241	28 4
Lower	294	34.6
Genitalia	5	0 6
TOTAL	850	100.0

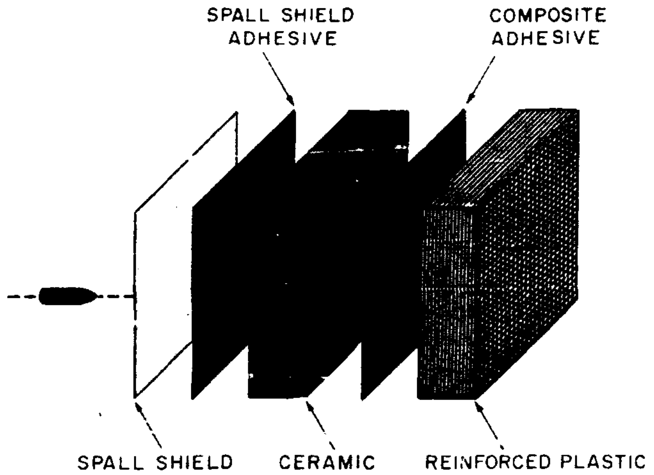

Fig. 1 Plastic-ceramic composite armor (expanded view). United States Army

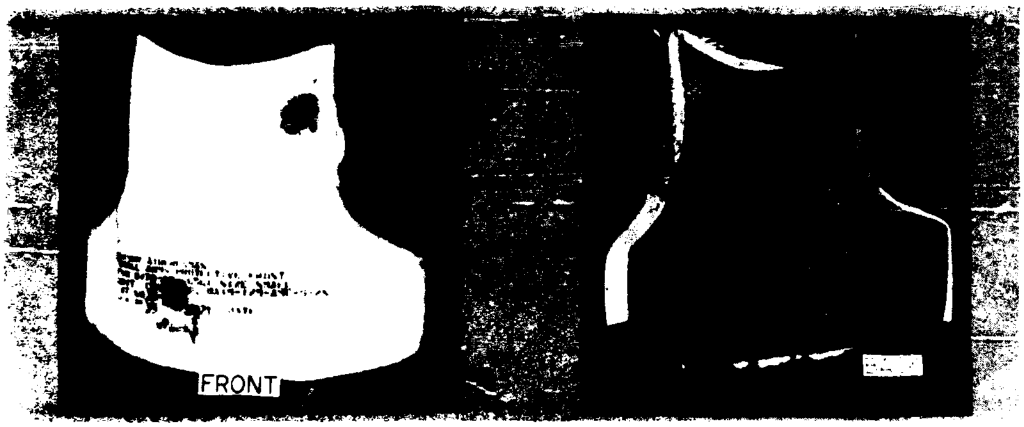

Fig. 2 Composite armor damage produced by ballistic impact of aircrew armor torso shields. United States Army

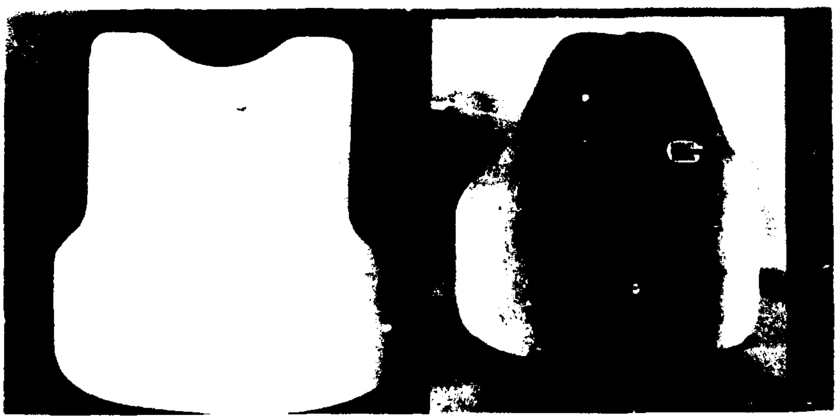

Fig. 3 Experimental torso shield - ceramic components (left - alumina: right - silicon carbide). United States Army

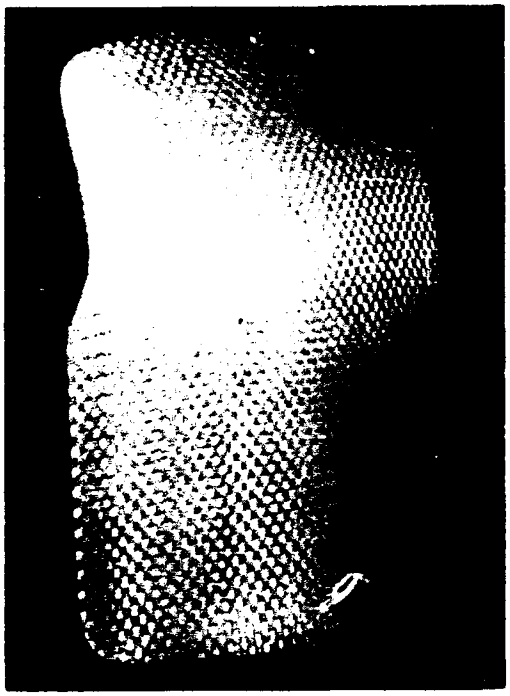

Fig.4 Experimental torso shield - reinforced plastic component. United States Army

Fig.5 Aircrew torso armor. United States Army

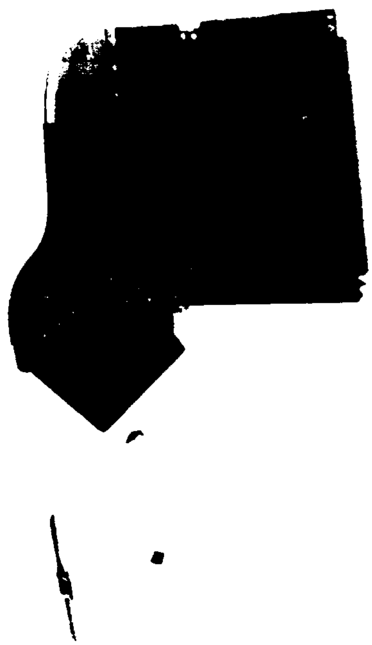

Fig.6 Armor panels for OH-6A (Cayuse) seats. United States Army

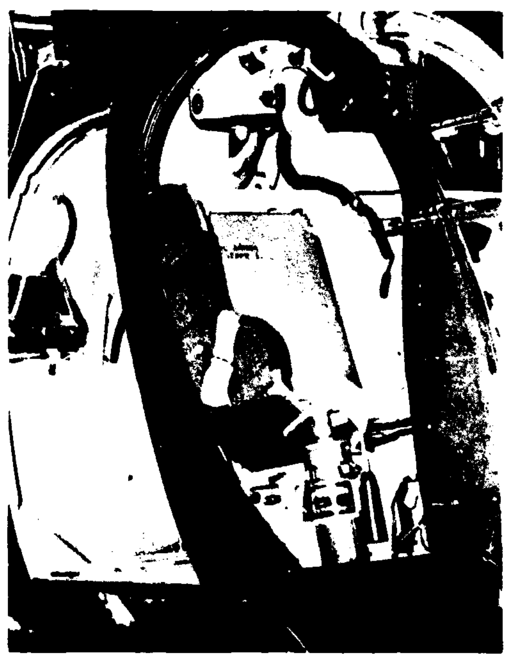

Fig.7 Armor installed on OH-6A (Cayuse) seat. United States Army

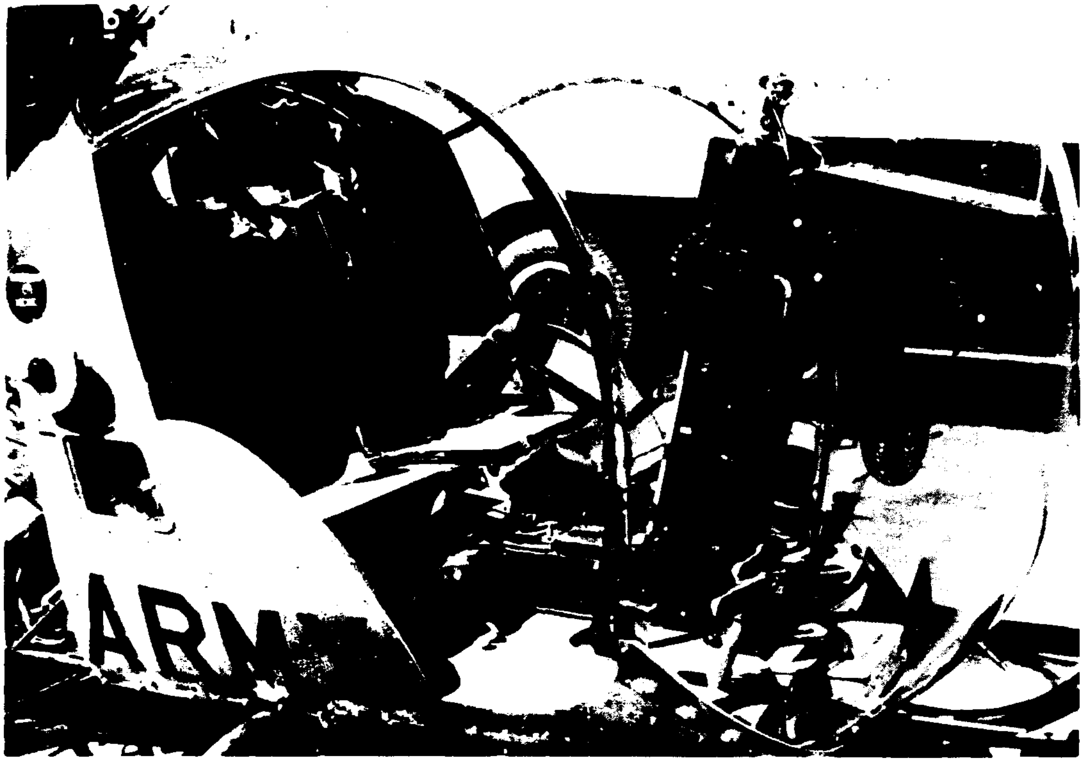

Fig. 8 Armor panels on OH-13 (Bell Sioux) seats. United States Army

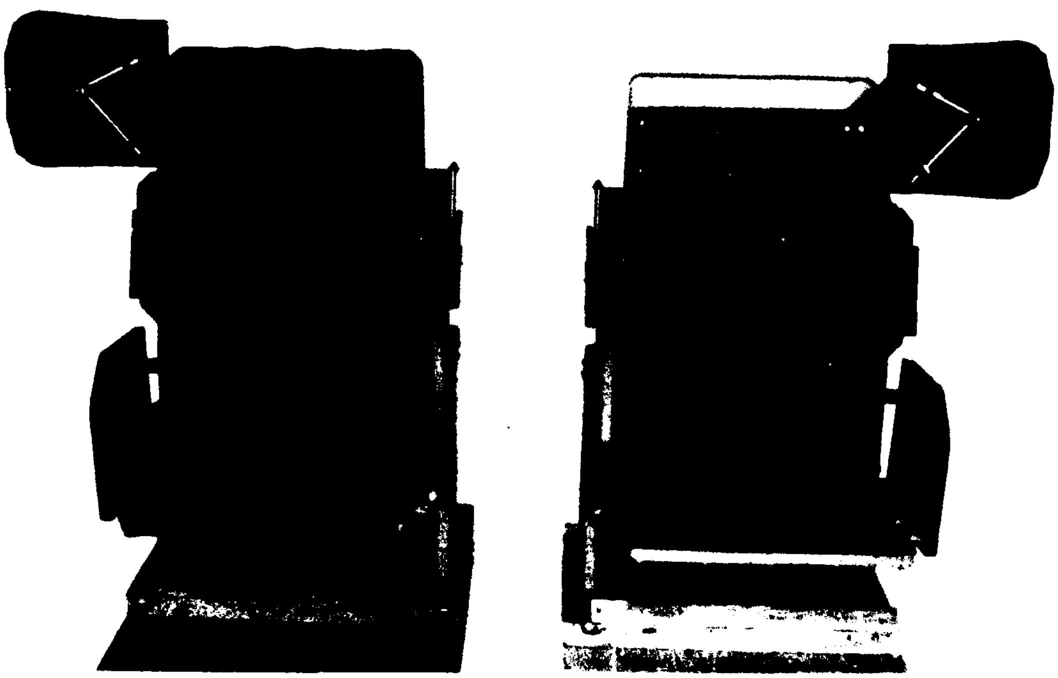

Fig. 9 Armored seats (pilot and copilot) for CH-47 (Chinook). United States Army

Fig. 10 UH-1 (Iroquois) armor seat. United States Army

Fig. 11 AM-16 (Cobra) armor seat (front view). United States Army

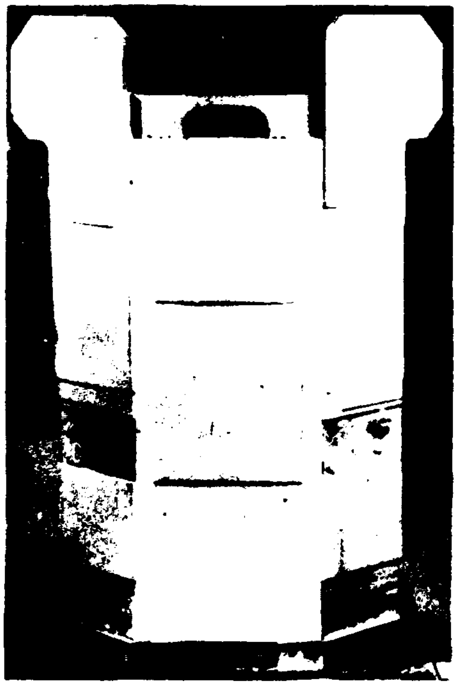

Fig. 12 AM-16 (Cobra) armor seat (back view). United States Army

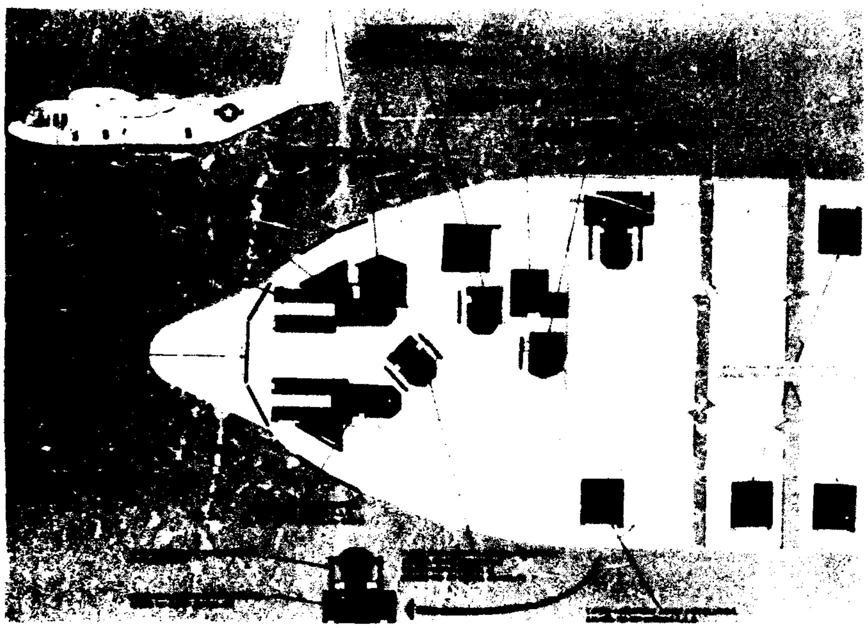

Fig.13 Armor locations on C-130 aircraft. United States Army

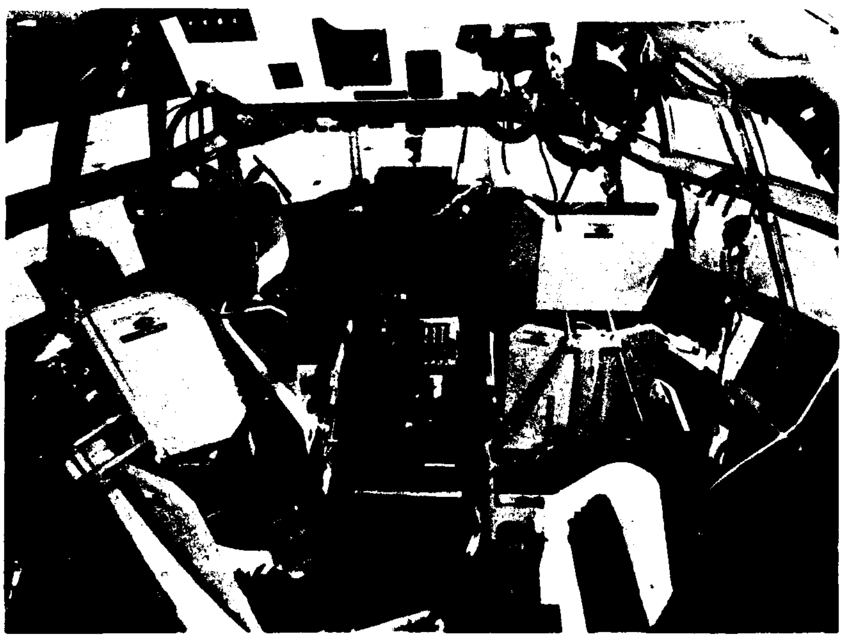

Fig.14 Forward armored seats on C-130. United States Army

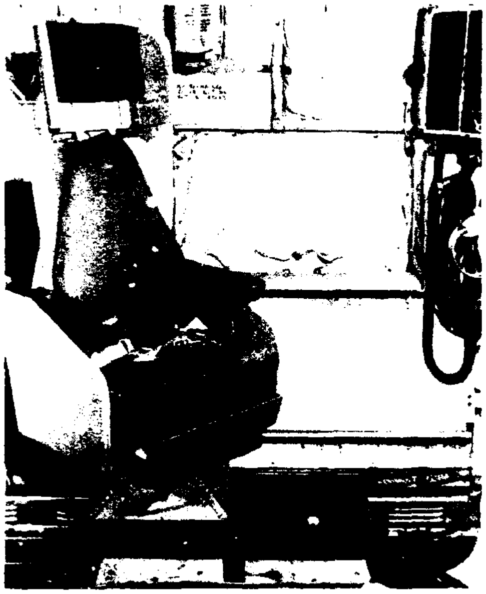

Fig.15 C-130 armored seat with cushions. United States Army

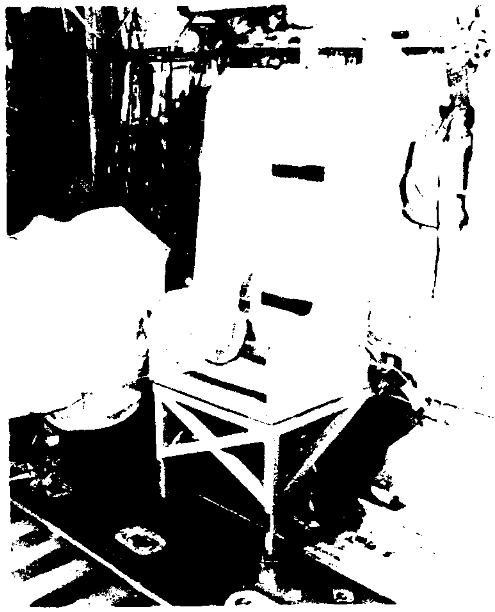

Fig.17 C-130 armored cargo-master seat. United States Army

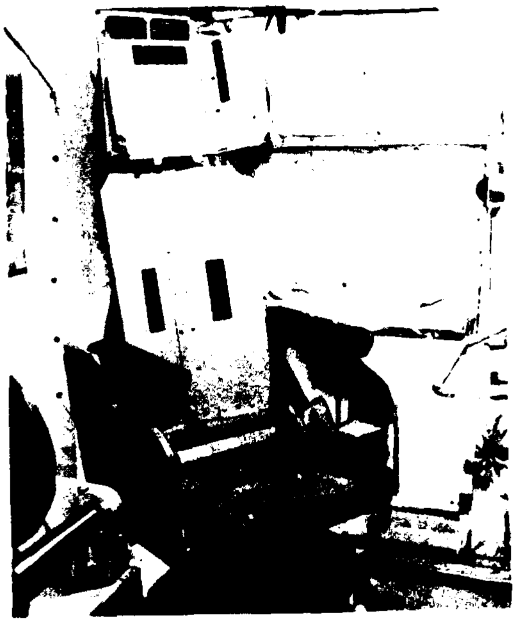

Fig.16 C-130 armored seat without cushions. United States Army

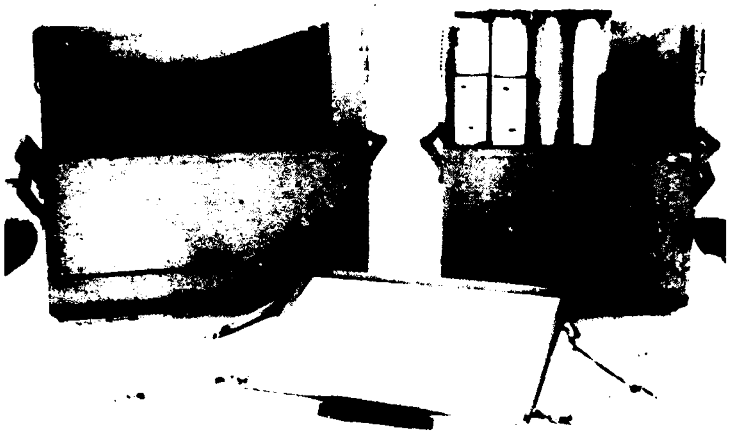

Fig. 18 Armored flare boxes. United States Army

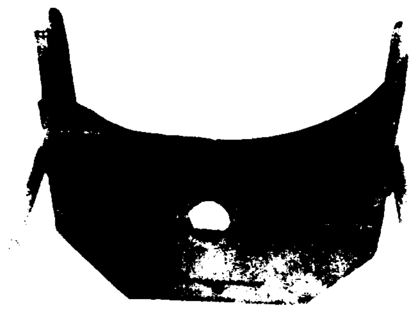

Fig. 19 Armor cover for OH-6 fuel control. United States Army

Fig. 20 Armor cover installed over OH-6 fuel control. United States Army

SAFETY IMPLICATIONS OF AIRCREW ARMOR AND ALLIED PERSONAL EQUIPMENT

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SUMMARY

Various items of aircrew armor are described. Safety implications and misadventures that have occurred in their use are noted. Suggestions are given for prevention of such occurrences.

VERY SHORTLY AFTER armies started using aircraft in warfare, prudent and intelligent airmen realized that some form of armor protection against hostile missiles was desirable. Historically, this realization is arrived at with each stage of warfare, whether on foot, on horse, or on helicopter. Unfortunately, the protection afforded is always associated with drawbacks. The Roman warrior had to develop calluses and expend extra energy to carry his shield and body armor. The mounted knight was helpless if unhorsed, and was frequently sorely bruised and chafed by day to day wear. Certain disadvantages persist in present day aircrew armor. Of course, most of the protective devices now in use have been developed during the Vietnam conflict with the accompanying huge expansion of the United States Army airmobility. Time was limited, but the need for protective equipment was urgent. Experience is providing valuable lessons, and improvements in existing armor surely will be forthcoming. Let's look at some now in use:

THE CHEST PROTECTOR

This is perhaps the most effective item of personal armor in use. It is composed of a rigid ceramic-metal composite plate held in position by a cloth carrier. The carrier has an external pocket in front which may be used to carry a survival kit, but which most frequently contains notebooks, cigarettes, and morphine syrettes. Depending on size worn and moisture absorbed by the carrier, the armor and carrier weigh approximately 12-14 pounds for the front plate alone or approximately 25 pounds if both front and back plates are worn. The pilot and copilot of most of our helicopters do not wear the back plates, as they are adequately protected by the armored seats. The crewchief and gunner, who frequently must stand and walk about while firing machine guns or performing their other duties, usually wear both. Some of the difficulties encountered with this device are:

WEIGHT--The weight of the armor contributes to fatigue. If the carrier is not tightened well about the lower chest, the weight pulls down excessively on the shoulders.

HEAT--If the carrier is well tightened, heat stress is increased because of the close approximation of the impervious armor plate in its heavy cloth carrier to large actively sweating areas. Certain of our aircraft have netting seats to allow air circulation to reach the back for cooling. One even has a forced air blower to cool the back. The effectiveness of these devices is greatly reduced, of course, by the wearing of armor. All these things contribute to physical fatigue and irritation. But until lighter weight materials can be fabricated for the body armor--and there already have been some applications of this--a certain amount of bulkiness must be accepted. Added weight and discomfort are being exchanged for at least partial protection of the Army airmen.

QUICK RELEASE--The armor recently has been provided with a quick release. This may well overcome difficulties experienced in a forced or crash landing where the armor's weight has been a detriment to rapid egress and escape. In the event of an unplanned water landing or crash, the weight has, in several cases, proven fatal. In these cases, individuals wearing armor have been seen to surface, apparently unhurt, only to subsequently drown. Others in the same or similar crashes have told of difficulties in doffing the device.

FLOTATION DIFFICULTIES--Presently available flotation devices are only marginally able to support a clothed, booted aviator with his personal sidearm, knife, and survival kit when an additional burden of armor is added. Besides this, the possibility of using the armor and flotation gear in conjunction with each other was not considered during the design stages. If the flotation gear is worn inside the armor, it is difficult to actuate inflation, and there is little space in which to inflate. If worn outside, over the bulk of the armor, it is susceptible to damage and to hanging up on controls, exits, etc. Worn external to the armor, it effectively prohibits doffing of the armor.

SPALLING--Another characteristic of the armor is that spalling is seen when the plate is struck by a missile. This spall contributes to secondary injuries, particularly to the face and eyes. In an attempt to contain this spall, members of many units wear the Korean War vintage nylon fragmentation protective vest (usually referred to as the "flak vest") over the armor plate or plates. This configuration further compounds the bulkiness problem, of course, and makes doffing the armor in the water well nigh impossible.

PARACHUTING--Our helicopter crewmen in RVN do not wear parachutes, so parachute problems for them have not arisen. Certain of our fixed wing crewmembers do wear parachutes, however, and some of them also wear armor. In most cases, they wear only the nylon vest. We have received no reports of anyone attempting to parachute while wearing the armor plates. In view of what we know about the behavior of the armor in crashes and from certain preliminary tests run by US Army developmental agencies, it is believed that serious or fatal injuries would result from the attempt, so we urge aviators not to try it. The parachute harness does not fit securely over the plates, which tend to flail around and upward with the parachute opening shock.

EJECTION--Crewmen who ride in ejection-seat-equipped aircraft do not wear the chest protectors, since cockpit armor provides some ballistic protection.

CRASH INJURIES--Thus far, injuries that have been attributed to the chest protectors (usually called "chicken plates" by the Army, and "hero boards" for some reason, by the USAF) have been confined to detached or loose teeth, bloody noses and lips, one possible broken jaw, and heavy bruises to the upper thighs. It is possible that more serious or fatal injuries to the larynx and trachea have occurred in more severe crashes and have not been reported or have been masked by postcrash burning. Injuries have been rare when the carrier has been properly sized and tightened. A loosely secured plate tends to ride up or down and cause some injury.

WEAR WITHOUT CARRIERS--Some individuals have, because of the heat of the carrier or because of fear of water landings, resorted to balancing the chest plate on their laps underneath the shoulder

straps. These individuals are confronted in a crash situation by a large, heavy, very rigid missile within the confines of the cabin, which has caused severe injuries.

BURNS--The nylon fragmentation vest has been implicated as contributing greatly to the severity of burns in some postcrash fires.

MAN-MACHINE INTERFERENCE--Finally, in at least two instances, helicopter crewmen with large chests have found that with their seats in the usual position, they could not move the controls fully back because of the added bulk of the armor. In fixed wing aircraft when a parachute is placed behind the pilot, the seat must be moved back in most cases so that full control movements can be attained.

UNEXPECTED BENEFITS--The subject of chest protectors should not be left without mentioning two good things that are accomplished by the armor besides stopping or slowing missiles: The nylon vest (flak vest) has been found to be a good supplemental flotation aid because of its construction (multiple layers of nylon encased in a plastic bag), and the chest plate is known to have absorbed and spread the impact of collision with controls or instrument panels, to the point that injury was markedly reduced in some crashes.

GROIN PROTECTORS

These are made of multiple layers of nylon in a manner similar to the flak vest. They are, perhaps unwisely, little worn by crewmembers. The first ones furnished had no means of fastening in place so that they threatened to slip down to the knees if one dared stand up or walk while wearing the device. They rode up, exposing the groin while sitting. They are principally used either for sitting upon (where they probably do little good except psychologically) or for placing in the chin bubble of the helicopter where, again, they do not slow or stop small arms fire effectively, but are valued psychologically.

HELMETS

The so-called "ballistic" helmet is not designed to defeat bullets. It has the capability of defeating low velocity fragments and secondary missiles roughly equivalent to that of the WW II M-1 steel helmet. It resembles the APH-5 helmet in general appearance and retention provisions. It is something more than a pound heavier than the APH-5, depending on the size. Consequently, it is more uncomfortable for long term wear and is more inclined to be lost during the crash sequence, thereby exposing its erstwhile wearer to injury. Like its predecessors, it is likely to cut the nose as it rotates forward off the head. The boom microphone, though superior to older models, has caused cheek injuries. Because of fitting and finishing problems, it has endangered flight by causing sweat to drip into the eyes. In not a few cases, excess glue has also melted and run down into the eyes.

SUPERIOR VISOR--The visor in this helmet is, however, of an improved polycarbonate material which is both flame resistant and shatter resistant. Several instances have been cited where faces and eyes were protected from fire and from shattered plexiglas and spall by the visor. Because of this excellent record, pilots have been ordered to fly with visors down at all times. Since flights take place at dawn, dusk, and night, as well as during full day, this means that most individuals must keep the clear visor inserted in the helmet and do not have the additional protection of a tinted visor against the glare of daytime flying. The webbing and lacing of the retention straps are made of nylon. This has contributed to the severity of burns in some cases.

LEG ARMOR

Various models of leg armor were sent to Vietnam for evaluation. To date, none has been found acceptable because of bulk, weight, and impedance to the helicopter crewmembers in their actions. No requirement for this item has been stated by airmen in Vietnam as of this time.

SEAT ARMOR, INCLUDING SIDE PANELS

Much good and little bad can be attributed to these devices. There have been difficulties in egress because of the jamming or inaccessibility of releases for the outboard side panels. These must be slid back to allow egress by the pilot and copilot of the UH-1. Because of this, unless the gunner or crewchief can come forward to slide the panels back from the outside, the usual pilot/copilot route of escape is backward, over the center console, and out one of the cargo doors unless the canopy happens to be conveniently missing. Occasional injuries are incurred by striking the sides of the armor during a crash.

POSSIBLE SOLUTIONS

Engineers, scientists, medical personnel, and other technical experts of the United States Army Materiel Command, The Surgeon General's office, and other military agencies constantly are checking aircrews, getting their reactions and seeking ways to improve protective equipment. Most of the drawbacks and bad features noted are already being worked on: The side panels on the armored seats are being fitted with improved releases. The chest protector carrier is being lightened and, in some cases, made of netting to allow ventilation. Quick releases for the armor plates were suggested and have been incorporated. Newer models of the armor plate will incorporate an antispalling layer (to reduce the problem of spall) so that the nylon flak vest will be

unnecessary. The US Navy, at least, is modifying their new lifevest, which already offers quite superior flotation capability, to be even more compatible with armor wear. Modification, including contour change and padding, is being evaluated to minimize the injury potential of the chest plate to neck, chin, and thighs. For fire protection, many of the cloth components are being or will be made of fire retardant materials. A new helmet with greatly increased comfort, coolness, and light weight is scheduled to be adopted shortly.

The problems for the would-be armor-wearing parachutist or ejectee are not yet solved, however. In view of the limited time and space available to him to prepare to exit, it is doubtful that a satisfactory solution will be found for personally worn armor. Instead, it appears that protection will have to be provided by the aircraft itself, such as is now done in the OV-1 Mohawk. This is, of course, the desirable course to forestall most of the problems noted thus far. It is discouraging to note that an experimental seat-mounted front protective armor was removed after a very short trial in one type of helicopter. Some individuals disliked having to reach through or around the device to manipulate the controls. It is felt that these individuals did not give the device or themselves sufficient time for evaluation.

Many more improvements are being studied and planned by a wide range of Army agencies and commands. They, no doubt, will produce better protection for pilots and aircrewmen. Increasing emphasis is being given to problems associated with the interactions among the equipment, the aircraft, and the man.

LIGHTWEIGHT BODY ARMOUR WITH A MULTI-HIT CAPABILITY

by

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Paper not available for publication

A NEW AIRCREW ARMOR VEST DEVELOPED FOR PROTECTION OF THE NECK AND OTHER PERIPHERAL REGIONS

by

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SUMMARY

The aircrew armor to be described was developed as a rapid response to a combat problem which had been identified by the Surgeon of the Seventh Air Force. The problem was that UC-123 aircraft flying low level missions were sustaining small arms hits. Aircrewmen in these aircraft were receiving wounds from secondary missiles produced from the aircraft's plastic canopy and aluminum skin. Although they were wearing flak vests of various types, there was an urgent need for additional body protection, especially in the neck area. Special armor was developed and sent to Southeast Asia.

Pilot attitudes toward wearing armor and user evaluations of the new armor were studied in 35 aircrewmen. In interviews and questionnaires, the past experience of pilots flying forward air control aircraft and aircrewmen assigned to the "Ranch Hand" Squadron (12 ACS) in Vietnam was evaluated. The study included evaluations in UC-123, 0-1, U-10, and A1E aircraft. Eighty percent of the aircrewmen interviewed had recent combat experience in Vietnam. This highly experienced group averaged 11.8 years of service and 10.7 years of flying experience. Collectively, the group had flown 8,775 combat missions and accumulated 13,660 combat hours. The study reports that USAF pilots want the best armor available but felt that the present body armor was only fair and improvements are needed. Primary criticisms were restriction of body movements, lack of protection from small arms fire, and the incompatibility of the present armor with other personal and aircraft equipment.

A NEW AIRCREW ARMOR VEST DEVELOPED FOR PROTECTION OF THE NECK AND OTHER PERIPHERAL REGIONS

THE SUCCESSFUL DEVELOPMENT of a weapon system is usually followed by the appearance of defensive countermeasures. To ward off blows from axes, spears, swords and daggers, the foot soldier of antiquity bore a shield of animal skin or wood. The Roman leather tunic was an effective battle garment for its day. The leather-stripped skirt provided additional protection for the wearer's groin and thighs. As weapons improved so did the technology of protective body armor. In recent years new concepts and new tactics have been developed which require aircraft originally designed for operation at higher altitudes to operate at very low altitudes or on the deck. One such case is the "Ranch Hand" defoliation missions presently being flown in Vietnam. Fairchild C-123 transport aircraft have been modified to include spray bars under each wing and at the rear fuselage and are used extensively in South Vietnam to defoliate Viet Cong jungle areas. Non-toxic defoliant enhances visibility in jungle areas by 80% within two weeks during the dry season. The C-123 aircraft were originally designed to haul cargo and operate from short runways. They normally operate below 14,000 feet (usually around 6000-8000 feet) at 150 knots true airspeed (172 mph). On the defoliation missions they fly at 100 feet altitudes and at 200 mph. Because of the requirement to deliver the defoliant from low levels, these aircraft are in a small arms fire environment.

THE PROBLEM

The C-123, like many other aircraft in use today, was designed when it was vogue to fly fast and high so that protection against small arms fire was not needed. Emphasis was on performance (especially range), altitude, speed, and countermeasures. Anything that degraded aircraft performance, like dead weight armor, was regarded with suspicion if not disdain. When these aircraft got to Vietnam and new concepts and tactics were developed, they began flying daily in the small arms ground fire environment and sustaining a substantial number of hits from small arms fire. Not unexpectedly, the modus operandi of failing to provide for armor during the design led to other problems in protecting the aircrewman, such as insufficient space and prohibitive weight to provide the needed protection by retrofitting the aircraft.

This was precisely the problem confronting the UC-123 defoliation aircrews in Vietnam who were now flying in a hostile environment. The aircraft was being hit almost daily by small arms fire and in numerous instances primary and secondary hits were sustained by the aircrew. In the winter of 1966, the 12th Air Commando Squadron in Vietnam requested that immediate action be undertaken by the research and development community to provide protection to their crews.

OPERATIONS ANALYSIS

In response to this request, the Aerospace Medical Division, working with the United States Army Natick Laboratories, initiated a quick-fix effort. As much information as possible was obtained on the defoliation missions of the C-123's. An analysis was undertaken to provide information on the requirement.

The needs for aircrew body armor differ from those of the other services because such protective garments must be worn in a cramped and uncomfortable environment and armor must be designed on the basis of an operations analysis of specific types of mission. To define the problem, seven basic considerations were evaluated:

a. Crew position for job function, movement, and protection requirements.

b. Flight regime. High or low level?

c. Mission type.

d. Caliber and hits being sustained.

e. Angle of obliquity.

f. Mission range requirements.

g. Tactics used and contemplated.

When the analysis was completed, it was concluded that the primary threat was 7.62 caliber armor-piercing bullets. The UC-123 aircraft design was studied and the aircrew's position in the aircraft time over the target area was determined to be about 6 to 10 minutes. From hit analysis it was evident that the front torso area, the neck, and the sides of the pilot were the most vulnerable. A few of the crewmembers had been able to obtain World War II flak vests and Korean War vintage infantry armor (see Figure 1). These offered only very limited protection to defeat primary and secondary missiles being encountered. In addition to direct hits from small arms, crews were sustaining injuries from ricocheting bullets and secondary missiles such as aluminum aircraft skin and plexiglass windscreen fragments and other aircraft parts. Several crewmembers had received hits in the neck area and at least one pilot had been fatally wounded by a projectile penetrating the neck.

DESIGN CHARACTERISTICS

Based upon a mission analysis of the UC-123 aircraft and the delivery techniques, these design characteristics were determined:

Optimum design for donning and doffing. The time from takeoff to the target area ranged from 1 to 1-1/2 hours. During this time the aircraft was able to fly above the range of the small arms fire. Because of the safe enroute flight, it was decided to design a vest that could be donned in the aircraft prior to arrival over the target area. A vest designed to open and close on one side best met this need.

Maximum area coverage for the neck. Because of the reported number of secondary missile hits in the neck area of the aircrews, it was essential that maximum protection be afforded this area. If possible, it was desired to protect the neck from the sternum to the pilot's helmet.

Maximum area coverage. The pilots of these aircraft sit in an armored seat that provides protection from directly below and behind the pilot. Because a direct frontal hit could be received from below and immediately in front of the pilot it was desired to provide maximum protection to the front torso area.

Regional distribution. Shown below is the regional distribution of wounded and killed in Korea. It can be seen that by protecting 39% of the body area, 89% of the lethal wounds would be prevented. The task of the aircrew armor designer is not to cover the entire body with protective materials -- this would restrict mobility -- but to select those areas which need maximum protection for the hazard and provide it.

REGIONAL DISTRIBUTION OF WOUNDS IN MEN
WOUNDED AND KILLED IN ACTION
(Infantrymen - Korea)
(Without Armor)

	Disabling	Lethal
Head	14.4%	40.0%
Neck	3.0%	3.0%
Thorax	19.0%	37.2%
Abdomen	11.0%	9.2%
Upper Extremities	25.6%	2.0%
Lower Extremities	27.0%	8.5%

S = USANL TR 67-40

Figure 2

Design concept. The design concept for the UC-123 aircrew armor was to provide maximum protection to the vital body organs with lesser protection to the peripheral areas or non-vital organs. Wound ballistic data was used to substantiate the relative vulnerability of vital areas of the thoracic and abdominal cavities which include the heart, great blood vessels, lungs, kidneys, spleen and spinal column.

Quick release for rapid doffing. Parachutes are not worn with the vests, but are available on the aircraft. If an aircraft is hi+ and is able to attain a higher altitude, the armor vest must be rapidly doffed and inflight egress accomplished via a parachute. If a crash landing is made, emergency ground egress needs to be accomplished in a minimum time and rapid removal of the vest is indicated in this situation. It was, therefore, decided that it should be possible to get the vest off in 3 to 5 seconds.

Mobility and weight. Mobility is a criterion that is equal in importance to protection for the aircrewmen. If the pilot cannot reach all the necessary controls and perform all the normal motions of piloting the aircraft, safety is compromised and serious consequences will result. It was initially felt that an absolute minimum weight was the most important criterion and, therefore, 20 pounds or less was established as a design criteria. It was desired to meet comfort requirements by designing for optimum weight distribution. Lastly, the vest had to be compatible with the other life support equipment of the pilot.

With the mission analysis completed and the design characteristics specified, an effort was initiated with the United States Army Natick Laboratories, Natick, Massachusetts. This laboratory is the focal point for the Army in personnel armor protection. There are numerous materials and combination of materials that provide various degrees of protection. This table shows that in the present state-of-the-art, protection is a function of weight. To provide small arms protection for .465 meter^2 at 6 to 7 psf areal density, the weight of the garment would be over 135 Kg. On the other hand, intermediate fragmentation protection can be provided for .465 meter^2 with about 5.4 Kg of armor protective materials. The task of the armor designer is to determine the optimum materials based upon the pilot's tasks to complete the mission and the particular hazards.

Ballistic testing. I will just briefly comment on ballistic testing. Armor ballistic determination methods and evaluation criteria vary in the United States with the service. However, the problem is basically the same -- defeat the projectile. The Air Force follows the criteria of the United States Army which is statistical in that they shoot their armor a number of times and compute a V_{50}. This V_{50} number is the velocity in feet per second, above which there is the same likelihood of penetration as below. V_0 is where all projectiles are stopped while V_{100} is where no projectiles are stopped. The projectile for tests is a 17-grain fragment. When these velocities are discussed in feet per second they refer to a 17-grain fragment fired at 110 meters at 0^{o} obliquity.

First prototype. In less than 30 days after the requirement was received the first prototypes were fabricated by the Natick Laboratories. Shown in Figure 3 is the first prototype. Protection provided to the front torso area is 7.62 caliber armor piercing at 0^{o} obliquity at 110 meters range. The shoulders, sides, lower torso and back provide fragmentation protection for approximately 335.3 meters per second for 17-grain fragments. The neck area provides fragmentation protection for 350.6 meters per second for 17-grain fragments. The chest area is protected for 810 meters per second. The vest provides the front torso protection by using a bullet-proof rigid chest plate which is made from a hard faced ceramic fiberglass composite structure. The peripheral areas are protected by ballistic nylon felt and layers of ballistic nylon woven material. The neck area has ballistic felt enclosed by three plies of ballistic nylon cloth encased in a lightweight nylon cover. The weight of the vest varies from 7.2 Kg to 9.0 Kg dependent upon size.

Chest plate. The ceramic-fiberglass composite weighs between .56 meter^2 and .84 meter^2. Tests have proved that this composite can defeat 7.62 caliber armor-piercing projectiles fired at point blank range. The extremely hard ceramic shell shatters the projectile and absorbs most of its kinetic energy. The resulting fragments are captured by a relatively soft fiberglass backing which also absorbs the remaining energy. After initial operational tests of six prototypes in Vietnam, minor design changes were made and a second group of prototype vests were operationally tested on actual missions (see Figure 4).

TEST AND EVALUATION

During the time the prototypes were being tested, a request was received from the training group for forward air controllers to evaluate the new armor. These pilots fly the 0-1 and 0-2 aircraft at relatively low altitudes to assist strike aircraft locate targets. At times it is necessary for them to fly in the small arms fire environment. Because of the interest of the FAC pilots, the UC-123 prototype vests were provided them for evaluation.

During August and September 1967, the Aerospace Medical Division conducted a study of pilot evaluations of existing aircrew armor and the newly developed UC-123 armor. Utilizing interviews and questionnaires, the past experience of 18 pilots flying forward air control aircraft and 17 aircrewmen assigned to the "Ranch Hand" Squadron in Vietnam was evaluated. The study included

evaluations in UC-123, 0-1 and 0-2 aircraft. Thirty-one of the 35 aircrewmen interviewed had recent combat experience in Vietnam. The forward air control evaluations were conducted by the members of the 4409th Combat Crew Training Squadron at Eglin AFB, Florida. The evaluations conducted by the "Ranch Hand" Squadron were accomplished by the 12th Air Commando Squadron in Vietnam. This highly experienced group averaged 11.8 years of service and 10.7 years flight experience. Collectively, the group had flown 8,775 combat missions and accumulated 13,660 combat hours.

In most cases the body armor that was available to pilots in Southeast Asia was the World War II or Korean circa body armor. Figure 5 shows the attitude of pilots towards protective garments. The difference between the operational situation of the UC-123 crews and the FAC crews should be noted. At the time of the evaluations, the UC-123 crews were flying daily combat missions in Southeast Asia while the forward air control pilots had returned and had been back in the United States from a period of three months to two years. When a pilot is being shot at daily, he is very anxious to have all the armor protection he can get. The summary of most of the aircrew evaluations is that they want the best protection available, but they feel that the presently available infantry armor has several disadvantages and needs improvement.

AIRCREW EVALUATIONS

What do you think of the body armor which is presently in use?

	UC-123	FAC
It is fair.	54%	33%
It is poor.	36%	9%
It is good although some improvements are needed.	12%	41%
One would be safer without armor.	0%	17%
It does a good job just as it is.	0%	0%

Figure 5

Figure 6 shows the general attitudes toward armor which were available. The armor evaluated was not designed specifically for aircrews, of course. Both groups felt that improvement is needed. About 90% of the UC-123 pilots rated the available armor as fair to poor, primarily because the armor did no. provide sufficient protection and coverage to the portions of the torso.

AIRCREW EVALUATIONS

In general, how do you feel about wearing body armor on combat flights?

	UC-123	FAC
I like the protection and always want to wear the best armor available.	90%	25%
Present body armor protection is desirable even though it is heavy, gets in the way, and makes it hard to do your job.	10%	35%
The advantages and disadvantages of wearing body armor are about equal.	0%	20%
The interference with operating efficiency outweighs the value of the protection furnished by body armor.	0%	15%
Body armor is so heavy and clumsy that one is safer without it.	0%	5%

Figure 6

Specific criticisms were grouped into these categories (Figure 7). All pilots indicated that the available armor partially restricts their ability to fly the aircraft and in some instances pilots stated it was unsafe for aircraft operation. A majority of the FAC pilots complained that they could not reach down in front of them to operate switches located below the height of the seat. Both the UC-123 and the FAC missions fly within the small arms environment. The present study brought out the fact that previously designed armor is not entirely compatible with other life support equipment such as survival gear and parachute, and, in some cases, the seat itself. One last point, the weight of the armor was, in all evaluations, the least criticized item. It was never listed as a specific criticism by the Ranch Hand pilots. This is in contrast to the ground soldier who must wear the armor throughout the day and where weight is a prime consideration.

AIRCREW EVALUATIONS

Criticisms (in broad categories) of present armor:

	UC-123	FAC
Restricts body movement	58%	85%
Does not provide small arms protection	90%	70%
Cannot reach some of the controls	6%	55%
Not compatible with other equipment	25%	60%
Too hot and uncomfortable	20%	65%
Too heavy	0%	6%

Figure 7

The pilots were asked to identify the body areas they wanted protected most. Figure 8 shows their listing. The probable reason for the UC-123 pilots listing the "head and neck" area as Number 1 is that their squadron had been experiencing a significant number of face and neck injuries from flying plexiglass and other secondary missiles such as aircraft skin and parts of the aircraft. One lesson learned on this study was that if the seat is not armored the pilot will sit on the first set of body armor and thus require two sets for protection.

AIRCREW EVALUATIONS

What body areas do you want protected most?

	UC-123	FAC
Head and neck	1	2
Chest	2	1
Abdomen (belly)	3	3
Groin (crotch)	4	4
Upper legs	5	5
Lower legs	6	6

Figure 8

Having discussed pilot attitudes toward body armor in general and presenting their evaluations of the presently available armor, certain basic differences between the armor requirements for the soldier and the aircrewman should be mentioned (Figure 9). The differences are important in establishing design criteria for new armor developments.

"Mobility" for the aircrewman is the non-interference of armor with the reach of the pilot and the lateral, vertical and forward movements required to adjust controls and search for ground or air targets. The front torso plate for some pilots almost precludes reaching some controls in the small forward air control aircraft. Obviously, armor developed for one specific aircraft and mission is not always suited for others. An absolute minimum of weight is not as important for the pilot as it is to the ground troops who must bear the entire weight of the garment. The pilot is normally in a sitting position on a mission of less than two hours duration and normally over a target only a few minutes. It is often possible to don the vest just before reaching the target area and remove it after leaving, thus necessitating only a few minutes rather than hours of wear.

Further design differences are that the soldier needs to don the armor garment rapidly while the pilot wants the capability to rapidly doff the garment. As to configuration, aircrew armor should be designed for specific aircraft and the mobility requirements for the particular mission.

AIRCREW EVALUATIONS

Differences between body armor requirements for aircrewmen and soldiers:

Pilot		Soldier
	Mobility	
Maximum to reach controls.		Moderate to perform combat duties.
	Weight	
Less important, short missions, sitting.		Be as lightweight as possible.
	Donning and Doffing	
Rapid doffing.		Rapid donning.
	Configuration	
Design for aircraft missions.		Versatile to accommodate many operational tasks.

Figure 9

Figure 10 shows the differences between evaluations in aircrews flying the different types of aircraft and missions. The UC-123 is a medium-size aircraft where the pilots can don the armor vest in-flight. Ninety percent of the FAC pilots indicated that they would need to put on their armor prior to takeoff. Also, of importance is the fact that 55% of the FAC pilots could not comfortably reach some of the aircraft controls when wearing the armor.

AIRCREW EVALUATIONS

If you are going to wear chest or chest and back armor on a mission, when will you put it on?

	UC-123	FAC
On the ground before entering the aircraft	11%	78%
In-flight prior to expected enemy contact	66%	11%
In the aircraft before takeoff	23%	11%
In the aircraft just after takeoff	0%	0%
Inflight after enemy contact	0%	0%

Figure 10

Presented below is an evaluation of how long the pilots felt they could satisfactorily perform their job while wearing a 20-pound armor vest with a six-inch fragmentation collar. Since most missions are less than two hours in duration, weight presents little problem to the pilot if the weight of the garment is properly distributed.

AIRCREW EVALUATIONS

How long do you think you can wear the torso front-neck fragmentation protection armor and perform your job satisfactorily?

	UC-123	FAC
Two hours	30%	61%
Four hours	12%	22%
One-half hour	12%	22%
Six hours or more	23%	11%
One hour	23%	5%

Figure 11

The UC-123 aircrew armor is a specialized development specifically tailored for the defoliation crews in Southeast Asia. Its development was based upon a specific request to provide protection in the neck area and peripheral torso area to defeat secondary missiles. The requirement was specific and, as can be seen below, the additional protection was felt to be a "very desirable" feature by 89% of the using squadron's aircrewmen. Below is the evaluation of this garment.

AIRCREW EVALUATIONS

Considering all factors, how do you feel about the protective collar on the torso front-neck fragmentation protection armor?

	UC-123
Very desirable feature	89%
Desirable feature	11%
Undesirable feature	0%

Figure 12

Shown below is a summary of the characteristics the pilots felt should be incorporated into the future design of aircrew armor. Air Force aircrewmen operating at low levels want and need armor protection from small arms fire. Body armor needs to be designed for compatibility with the various aircraft and the life support equipment worn by the aircrewmen. It is important that the design and materials selected are able to be used in a manner which promotes articulation, flexibility, and mobility. Low weight and low bulk are less important than the above characteristics.

DESIRED CHARACTERISTICS

1. Maximum ballistic protection feasible for small arms fire and fragmentation ordinance.
2. Armor not a source of secondary fragmentation.
3. Compatible with or integrated into other life support equipment.
4. Flash and flame resistant.
5. Optimum degree of flexible response by the pilot engaged in the operation of the aircraft.
6. Be non-magnetic so as not to impair aircraft instruments.
7. Be easily donned and doffed by the aircrewmen.
8. Materials should be non-toxic and non-irritating and should not cause serious complications to wounds.

Figure 13

One final note on the high acceptance by the UC-123 defoliation squadron. On 16 June 1968, Major J. W. Gentry was flying on a low level defoliation mission over South Vietnam when a bullet from an AK-47 penetrated the aircraft from below and directly in front of Major Gentry. The bullet struck the ceramic plate and then the collar of the vest. Upon landing the aircraft, the projectile was found caught in the collar of the vest. Although this pilot sustained a badly bruised neck, his life was undoubtedly saved by the armor and he is still flying daily with his defoliation squadron.

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Figure 1 - World War II Flak Vest.

Figure 3 - First Prototype.

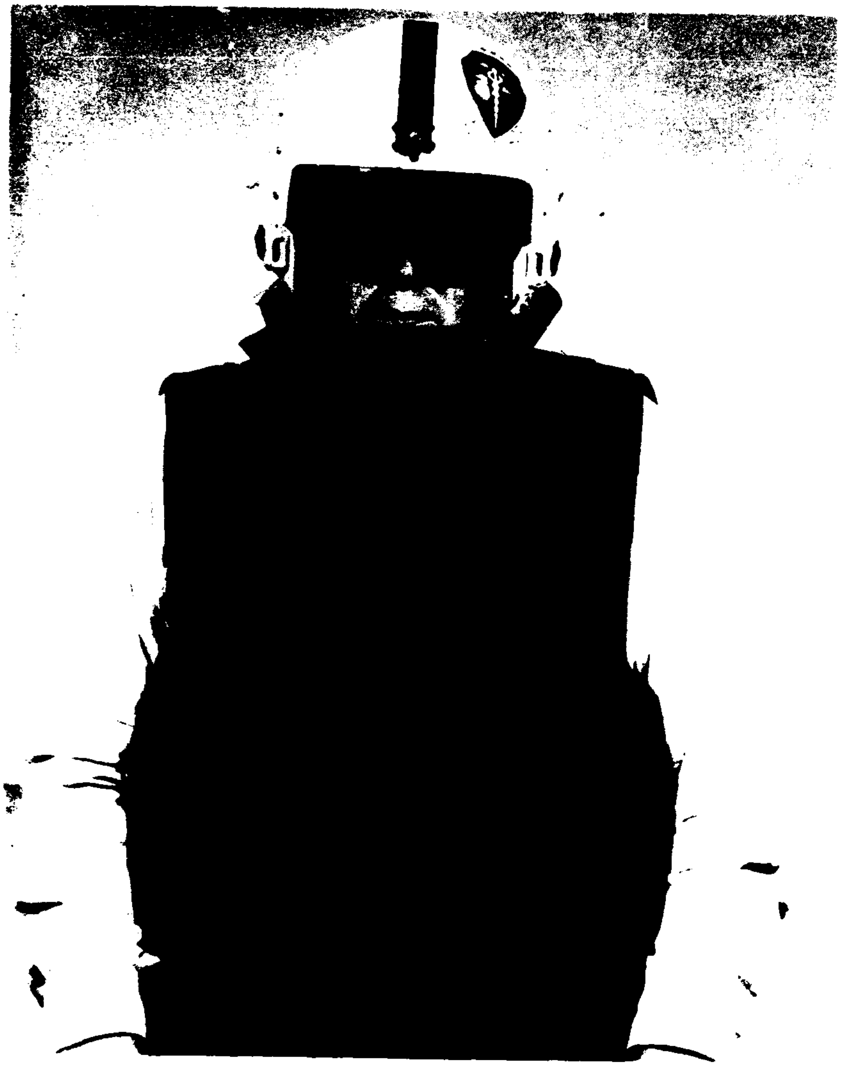

Figure 4 - Second Prototype.

LE GILET DE PROTECTION PARE-BALLE

Capitaine G.C. LEOMAND

Ingénieur Civil de l'Aéronautique

DIRECTION DES RECHERCHES ET MOYENS D'ESSAIS

PARIS FRANCE

HISTORIQUE DE LA QUESTION EN FRANCE

Ce n'est pas pour donner un certain sentiment de sécurité aux combattants que les Etats-Majors Français ont dôté les troupes de protections corporelles individuelles:

Des statistiques internationales effectuées tant après la guerre de 1914-1918 qu'après celle de 1939-1945 donnent globalement la répartition suivante des blessures à la tête, aux membres et au tronc:

- blessures à la tête	:	5% des blessés,
- blessures aux membres	:	22% des blessés,
- blessures au tronc	:	75% des blessés.

D'une manière générale, on peut même penser que les blessures à la tête et au tronc entraînent la mise hors combat définitive.

Notons également que cette statistique rend surtout compte de la répartition des blessures chez les Fantassins.

Ainsi, la tradition millénaire des protections individuelles survit-elle à nos jours, et, en 1953 l'Inspection Technique de l'Habillement était chargée de l'étude et de la réalisation d'un gilet pare-balles.

Parallèlement, cette protection du tronc des équipages naviguant (pilotes et navigateurs) était complétée par des slips et baquets pare-balle, dont les caractéristiques étaient données par le commissariat de l'Air.

Les slips étaient en tissu polyamide et munis de plaquettes polyester ajustées les unes près des autres pour une bonne adaptation aux individus.

Le baquet comportait un fond rigide, et ses côtés comportaient également des plaquettes de polyester.

Malheureusement, dès les premières expérimentations, il s'est avéré que ce matériel était totalement inadapté. Il restreignait la liberté de manoeuvre du personnel, et procurait une gêne considérable après un certain temps d'utilisation. Ce qui fait que ce genre de protection a rapidement été abandonné et remplacé par un blindage des habitacles.

Le gilet de protection pare-balles a, au contraire, été largement utilisé. Deux types différents de matériels ont été étudiés:

- Un type de gilet constitué d'un matelas de plusieurs épaisseurs de tissus synthétiques reliés entre eux par un matériau plastique;

- Un type de gilet constitué de plusieurs épaisseurs de tissus synthétiques formant des alvéoles pouvant contenir des plaques soit en métal soit en verre stratifié.

Le gilet constitué d'un matelas de plusieurs épaisseurs reliées entre elles par un matériau plastique, une colle, s'est révelé d'une trés grande efficacité contre les corps tranchants animés d'une faible vitesse comme par exemple certains éclats; mais cette protection était pratiquement nulle devant les projectiles rapides tels que les balles.

Le gilet constitué de plusieurs épaisseurs de tissus synthétiques formant des alvéoles pouvant contenir des plaquettes de protection, a été experimenté initialement avec des plaquettes :

a) - en acier au manganèse,
b) - en alliage de titane,
c) - en stratifié verre polyester.

Les plaquettes en acier au manganèse ont donné satisfaction, mais, pour des performances trés comparables à celles obtenues avec des matériaux synthétiques, le poids était prohibitif.

Les plaquettes réalisées en alliage de titane n'ont également pas été retenues car l'alliage de titane élaboré à cette époque présentait une résilience insuffisante.

Seules les plaquettes en stratifié verre polyester ont été retenues.

DESCRIPTION DU GILET PARE-BALLE

Deux types de gilet pare-balle ont été réalisés; ils diffèrent entre eux uniquement par leur forme, le principe de protection étant identique dans les deux cas.

Le premier type est dit "forme veste", et le second "forme chasuble".

Nous décrirons le gilet "forme chasuble".

Le gilet est destiné à protéger la partie supérieure du corps. Il affecte la forme d'une chasuble sans manche; il s'enfile par une ouverture formant encolure, destinée au passage de la tête.

Il est constitué d'un devant et d'un dos, réunis entre eux par une partie double en tissus de nylon, formant une épaulière de 14 centimètres environ de développement. Cette épaulière est renforcée par quatre feuilles de nylon haute ténacité solidaires entre elles.

La protection est assurée sur le devant et sur le dos du corps par des plaquettes galbées, carrées, en plastique stratifié.

Cette protection se présente comme une carapace d'écailles, se recouvrant de la gauche vers la droite dans le sens horizontal; les rangées horizontales, indépendantes les unes des autres se recouvrent du haut vers le bas.

Cette disposition en écailles est assurée grâce à des alvéoles dans lesquelles sont glissées les plaquettes. Ces alvéoles comportent 2 volets latéraux en tissus élastiques de 40 millimètres de largeur et permettent un éventuel remplacement des plaquettes.

L'ensemble de la cuirasse est enfermée dans une enveloppe en tissus nylon, d'un poids approximatif de 250 grammes au mètre carré, fermée sur trois côtés et renforcée intérieurement par une sangle en tissus de lin, de 20 millimètres de largeur, sur laquelle sont fixés des boutons pressions permettant la fermeture de l'enveloppe.

Le gilet comporte un nombre total de 32 plaquettes.

- Sur le devant, 14 plaquettes disposées de haut en bas:
  - 2 rangées horizontales de 3,
  - 2 rangées horizontales de 4.

- Sur le dos du gilet, 18 plaquettes disposées de haut en bas:
  - 2 rangées horizontales de 3,
  - 2 rangées horizontales de 6.

Sur la partie avant du gilet, au-dessous du bord inférieur de la dernière rangée de plaquettes à 50 millimètres du liseret, le gilet est prolongé par une plaque ventrale appelée bavette de protection.

Cette bavette est constituée d'une enveloppe tissus de nylon dans laquelle est insérée un matelas de 13 épaisseurs de nylon haute ténacité.

Le plaquage du gilet sur le corps est assuré au moyen d'une ceinture de serrage, fixée sur l'enveloppe extérieure du dos, fermée par une boucle sur la partie ventrale.

Une fois en place et ajusté, les bords latéraux du devant du gilet recouvrent les bords latéraux du dos, et les emmanchures doivent être suffisamment échancrées pour ne pas blesser et permettre tous les mouvements du bras.

Enfin ce gilet comporte 2 poches de poitrine.

Equipé et fini, le gilet de protection pèse en moyenne 5,400 kgs.

LES PLAQUETTES DE PROTECTION

Les plaquettes de protection sont en matériaux composite à matière organique, résine polyester renforcée de tissus de verre. Les plaquettes sont constituées par 3 plis (ou 3 couches) de tissus de verre. Ces plaquettes de 130 millimètres de côté, sont galbées dans un sens: la flèche maximum est de 10 millimètres. Les bords sont arrondis à un rayon de 8 millimètres. L'épaisseur des plaques est de 4 millimètres. Le poids moyen est de 125 grammes avec une tolérance de + 5 - 8 millimètres.

Les caractéristiques auxquelles les contrôles de réception attachent de l'importance sont les suivantes:

- le poids,
- la prise d'humidité ou augmentation de poids après immersion,
- la perforation,
- les dimensions et la finition.

La prise d'humidité est importante, en effet, l'eau dont s'impreigne le matériau composite modifie les liaisons matrices renforcement, ce qui entraîne en général un délaminage plus rapide du matériau soumis à l'impact d'une balle.

Les normes de caractérisation ont fixé en France que la prise d'humidité ne devait pas dépasser 2% après immersion pendant une heure dans l'eau proche de l'ébullition (la température est comprise entre 90 et 100° C).

Au contrôle de réception du matériel, les essais sont effectués sur les plaques les plus légères.

Les essais de perforation correspondent aux performances réelles envisagées du matériau, qui sont de résister sans perforation totale à un impact d'une énergie de 2.10^4 K J/m2 ou encore représentant une quantité de mouvements de 80.10^3 Kg.m/s/m2, ce qui correspond aux performances d'un projectile de pistolet mitrailleur M.A.T. 49, tiré au cours d'un combat rapproché.

Les plaques qui présentent une trop grande rigidité sont perforées ainsi que celles dont les couches se délaminent trop aisément.

Les essais de perforation sont effectués sur les plaques les plus légères des lots contrôlés, quatre heures après l'essai de prise d'humidité.

La face concave des plaquettes prend appui sur un pneumatique simulant grossièrement l'élasticité que représente le tronc du combattant, les bords curvilignes étant horizontaux.

Au cours des essais, les projectiles doivent être arrêtés si leur impact se situe à une distance supérieure à 10 millimètres de la bordure des plaquettes; à une distance inférieure, on peut tolérer la perforation sans inconvénient puisqu'il y a chevauchement des plaquettes.

Une plaque peut arrêter plusieurs projectiles, si leurs points d'impact sont suffisamment espacés, en particulier, il faut qu'un nouvel impact n'ait pas lieu dans une zone délaminée par un impact précédent.

Ainsi, au cours des essais de réception, les plaques comportant un impact dans leur bordure (a moins de 10 millimètres du bord) sont à nouveau soumises à l'épreuve des balles.

L'arrêt du projectile déforme la plaque: les plis se délaminent sur une surface plus ou moins grande et on observe un gonflement.

Chacun des plis du matériau agit comme une barrière d'arrêt, et c'est son énergie de déformation qui permet le ralentissement du projectile. Le contrôle de ces déformations donne une indication sur la cohésion du matériau et sur la tenue des fibres de renforcement.

C'est ce qui conduit à limiter à 25 millimètres les déformations acceptables en cours d'essais de réception. Cette déformation est en outre compatible avec la géométrie de l'assemblage pour ne pas entraîner de blessures.

L'utilité du dernier contrôle, celui des dimensions et de la finission, apparaît comme évident.

COMPORTEMENT DES COMBATTANTS EQUIPES DU GILET

Le gilet pare-balle Français a été utilisé principalement au cours de la guerre d'Indochine et celle d'Algérie.

En Indochine, l'hélicoptère a été peu utilisé; d'autre part le blindage du poste de pilotage avait été préféré aux protections individuelles, ce qui limite considérablement l'expérimentation de l'efficacité du vêtement pour le personnel navigant.

Les résultats d'utilisation des gilets pare-balle en cours d'opérations militaires sont donnés par des rapports émanant d'unités combattantes et portant sur quelques milliers de cas. Les aspects essentiels qui peuvent être dégagés de ces rapports concernent:

- Le comportement des gilets,
- L'efficacité de protection du personnel,
- L'efficacité psychologique,
- Les incompatibilités ou lacunes,
- Les suggestions formulées par les utilisateurs.

COMPORTEMENT DES GILETS.

Il apparaît que les méthodes de contrôle de réception des plaquettes de protection sont suffisamment efficaces pour déceler des dispersions dans les caractéristiques. En effet, sauf pour quelques rares cas isolés, les projectiles à bout rond d'une énergie équivalente à 2.10^4.K J/,2 ont été arrêtés.

Nous n'avons malheureusement aucun renseignement concernant les gilets qui ont été traversés, en particulier on ne peut conclure ni à un vieillissement prématuré ni à une disposition fortuite des caractéristiques.

Parrallèlement, on constate que les balles à bout rond arrondi ou conique traversent généralement les gilets, mais la trajectoire est toujours considérablement déviée.

La résistance à l'usure de ces gilets semble assez modeste. Les plaquettes, bien qu'ayant des bords arrondis, usent rapidement le tissu des alvéoles et le recouvrement des écailles n'est plus assuré.

EFFICACITE DE PROTECTION DES PERSONNELS

L'efficacité des gilets est indéniable: chaque fois qu'il a été possible d'expérimenter ce matériel en combat, les rapports sont unanimes à reconnaître que les combattants atteints au thorax doivent leur vie sauve au port du gilet.

On remarque cependant qu'un certain nombre de combattants porteurs de gilets ont été blessés, même par des projectiles à bout rond. Il s'agit souvent de projectiles pénétrant à la jointure de deux plaquettes. Ceci met en évidence l'importance du positionnement des plaquettes, compromis par l'usure des alvéoles.

Le gilet s'est avéré également efficace dans la protection contre les éclats légers d'obus et de grenades.

Enfin, il n'est fait mention dans les rapports ni de blessures secondaires dues aux déformations des plaquettes après un impact, ni de complications des blessures causées par des fragments de protection entraînés par le projectile.

EFFICACITE PSYCHOLOGIQUE

Dans ce domaine encore, le port du gilet a une action efficace. Cet effet se révèle particulièrement chez les combattants exposés, pour qui le souci de se protéger est incompatible avec l'exécution de la mission : chauffeurs de véhicules non blindés, servants d'armes automatiques de bord, radios sur véhicules, pilotes et observateurs. Le personnel équipé de ce matériel fait preuve d'une telle confiance que certains rapports ne mentionnent qu'un seul avantage présenté par les gilets pare-balle : celui d'être un excellent élément pour le moral du combattant.

LES INCOMPATIBILITES OU LACUNES - SUGGESTIONS

Malheureusement on remarque également un certain nombre de défauts signalés par les utilisateurs.

Les critiques formulées portent essentiellement sur les points suivants:

- le poids,
- la chaleur,
- l'ajustement du vêtement,
- la protection du cou, de l'abdomen.

LE POIDS.

Le poids est le reproche le plus fréquemment fait à ce vêtement, au point que son utilisation n'est plus envisagée que pour le personnel transporté le plus exposé.

On semble admettre en effet que l'excès de fatique due au poids est prohibitif. La limite de poids communément admise est de l'ordre de 2 Kgs.

Comme d'autre part la tendance générale est à l'augmentation des surfaces de protection, ceci conduit à réduire de plus de la moitié la densité des protections, donc d'atteindre une densité voisine de 1,4 pour une efficacité de blindage équivalente.

LA CHALEUR.

La chaleur rend insupportable le port du gilet, pour le fantassin comme pour l'équipage navigant dans les régions chaudes. Ceci provient de ce que l'enveloppe du gilet est constituée en tissu de nylon imperméabilisé à une pression d'eau de 280 millimètres d'eau mesurée à l'appareil SCHNERBER, empêchant ainsi l'évaporation de la transpiration. Il semble donc souhaitable de réaliser ces gilets en tissu dont l'aération optimum doit être compatible avec la résistance mécanique exigée.

L'AJUSTEMENT DU VETEMENT.

L'ajustement du vêtement, indispensable pour une efficacité optimum, rend par contre trés difficile tous les mouvements de flexion du tronc. Il faut signaler cependant que cette gêne est compensée chez certains par une diminution de la fatigue éprouvée à la suite de longs déplacements grâce au maintien du tronc par le gilet. Néanmoins, la majorité des rapports soulignent la gêne; l'été le gilet porté sur un vêtement léger cause rapidement des blessures; l'hiver, il est porté par dessus un habillement épais, il rend mal aisé tous les mouvements. C'est ainsi par exemple que l'échancrure de l'épaule, juste suffisante quand le gilet est porté sur une simple chemise, ne l'est plus quand le gilet est porté par dessus quelques épaisseurs de tissu.

LA PROTECTION DU COU.

La protection du cou est totalement inexistante et elle est unanimement regrettée.

LA PROTECTION DE L'ABDOMEN.

La protection de l'abdomen est vivement souhaitée par tous. Cependant, c'est curieusement la longueur du vêtement qui est jugée responsable de la majeure part de l'inconfort; c'est ainsi que la bavette de protection ventrale est jugée une gêne intolérable dans la manoeuvre des jambes des chauffeurs ou des pilotes. La protection réclamée le plus souvent semble devoir couvrir l'abdomen jusqu'à l'aine, lorsque le combattant est en position assise.

En conclusion, si l'on devait décrire le gilet pare-balle idéal, on pourrait citer les caractéristiques suivantes:

- être léger et peser 2Kg au maximum,
- être souple,
- être frais l'été, chaud l'hiver,
- protéger l'abdomen, le tronc, le cou,
- et être efficace contre tous les projectiles, même tirés à courte distance.

Enfin, nous voudrions remercier la Section Technique de l'Armée ainsi que l'Inspection Technique de l'Habillement pour l'aide précieuse que ces organismes nous ont apportée.

Fig.1 Gilet forme veste

Fig.2 Gilet forme chasuble

Fig.3 Impact dans une plaquette de protection

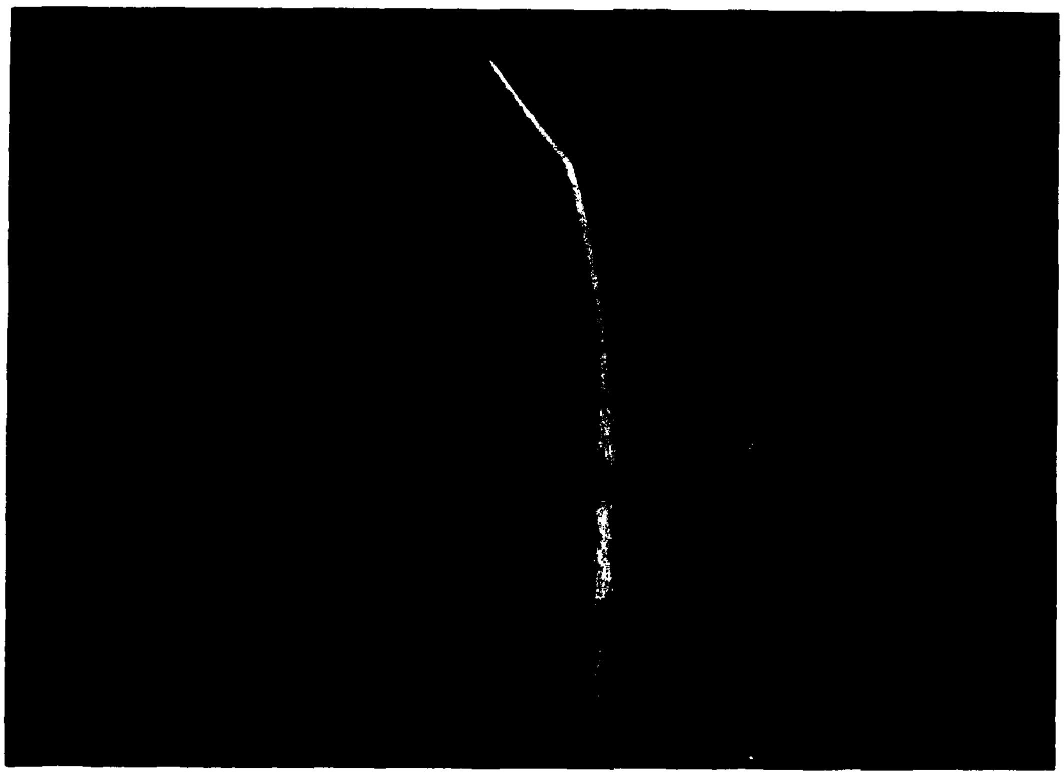

Fig.4 Delaminage après impact

DEVELOPMENT OF AN AIRCREW SAFETY HARNESS WITH SPECIAL REFERENCE TO THE F111 AIRCRAFT

by

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SUMMARY

The principles of safety harness design are discussed and a method of harness assessment is presented. As an illustration the development and assessment of an alternative British harness for the F111 is described.

The British harness was compared with the American harness in experiments, conducted first at low levels of acceleration (1 G) and then at higher levels (up to 17 G) induced by swinging human subjects in a suspended replica F111 seat and arresting the swing with cables.

The improved restraint afforded by the British harness coupled with its operational advantages has led to its acceptance as a replacement for the American harness in all F111 aircraft.

PRINCIPLES OF AIRCREW SAFETY HARNESS DESIGN

THE FUNCTION OF a safety harness is to restrain aircrew against all forces which can occur in flight, on the ground, or during emergency escape. The harness must be efficient without over-restriction, and must accommodate all sizes of personnel who are to use it. It should be simple, comfortable and easy to use. Quick release connections to the parachute and the seat must be incorporated so that the time for emergency egress is minimal both in the air and on the ground, whilst retaining the support and restraint of the harness and parachute when required. Preferably, seat and harness should be designed together, enabling the seat and harness anchorage points to be strong where required with the minimum weight penalty. Harnesses will differ with the role of the aircraft, as the crew of a transport aircraft need less restraint than a fighter pilot. Cockpit size will also influence harness design as more freedom is required in larger cockpits. The harness should also allow, where necessary, special tasks, eg, leaning forward to view a radar screen, to be performed without any compromise of restraint which unfastening the harness would entail.

A METHOD OF HARNESS ASSESSMENT

The assessment of a harness must include tests which simulate as far as possible the worst conditions and combinations of stress to which the harness may be subjected in use. Stress should be graduated, so that failures can be detected early in the assessment and be corrected. The primary function, that of restraint, should be assessed first.

An acceleration of 1 G can be imposed in various directions by tilting and inverting the seat, harness and subject with respect to gravity. Higher levels of acceleration can be imposed by arresting the motion of the seat and the subject with decelerating cables. Alteration of the seat position with respect to the motion will alter the plane of imposed deceleration.

If the harness is also to be used as a parachute harness, eg, as the combined parachute and seat harness of an ejection seat, the harness should also be assessed in that role. Human subjects wearing the harness should be exposed to vertical accelerations equivalent to those caused by parachute development and subsequent suspension. This can be effected by suspending the subject wearing the harness by the parachute risers or lift webs. The vertical acceleration produced by parachute development can be simulated by raising the subject so that the risers become slack and then allowing the subject to fall until arrested by the tension in the risers. Varying the distance of fall before arrest will vary the imposed vertical acceleration.

Following restraint, other variables such as comfort, ease of use, restriction to movement, and the ability to reach all controls and accommodate all aircrew sizes should be assessed with the seat placed in a three dimensional replica of a suitable cockpit.

The results of all assessments should be applied to improve the overall design before the harness is introduced for service.

DEVELOPMENT OF AN ALTERNATIVE HARNESS FOR THE F111

The F111 employs crew module or capsule ejection as a means of emergency escape. The crew module containing two aircrew separates from the aircraft by rocket power and descends by means of a parachute. The escape system can operate throughout the whole performance envelope of the aircraft, and the crew remain in the module until after ground or water impact. As the crew module can impact with forward and lateral motion in addition to vertical descent, forward, lateral and vertical acceleration can be imposed on the occupants.

A simple harness is required for the F111 crew module seat, which restrains the aircrew against forward, lateral or vertical acceleration in any combination, but which does not impede emergency egress. Before separation of the crew module, the harness is tightened automatically by powered retraction of the shoulder straps.

THE AMERICAN F111 HARNESS. This harness (Fig 1), which is fitted to all F111 aircraft, is in two portions. Lower torso restraint is by means of two fixed lap belts which fasten by buckles to a pelvic crutch loop attached to the seat pan. Upper torso restraint is basically of cruciform design with additional lateral restraint. Two combined straps hook together at a central quick release buckle. Each combined strap consists of a shoulder strap, a torso strap and a chest strap which passes behind the subject to the other side of the seat frame. The shoulder straps extend forwards on demand and are reeled in automatically. Only the crutch loop and chest strap can be adjusted.

The buckles of this harness and the "waistcoat" nature of the upper torso portion impede rapid egress. The fixed length torso strap prevents personnel with very large chests using the harness and allows the shoulder straps, when automatically retracted, to pull the central buckle dangerously near the throat of small chested aircrew. The lower torso restraint provides a loop in which the pelvis can pivot up or down, and this is not prevented by tightening the strap.

THE BRITISH HARNESS. An alternative harness (Fig 2) for the F111 was developed at the Royal Air Force Institute of Aviation Medicine. It is a simple harness incorporating a four-point quick release box, which is attached to the seat pan by a fixed length negative G restraint strap. A pair of lap straps incorporating roller adjustment buckles end in lugs which are inserted into the

quick release box. A pair of shoulder straps which fasten at the quick release box are passed through an adjusting buckle to a small roller at each side of the chest. These shoulder straps are themselves attached to the seat by a second pair of straps which descend from the inertia reel, pass through the rollers, turn back and are fastened to the other side of the seat. This double shoulder strap assembly is carried on a "horse collar" shaped pad, which distributes the tension of the straps over a wider area, keeps the rollers in the most effective position and prevents clothing jamming the rollers.

The lap and negative G straps enclose the pelvis and prevent vertical movement when the module is inverted or subjected to vertical oscillation. The shoulder straps prevent forward movement of the upper torso, and the crossed shoulder straps prevent vertical and lateral movements. Despite the close restraint provided by the harness, the single action of turning the quick release box releases all straps from the body. The buckles in the straps allow adjustment for all sizes of aircrew and enable the pilot to tighten the harness and obtain additional restraint when required.

As the British harness showed promise it was assessed and compared with the American harness at both low (Reader, 1967a) and high (Reader, 1967b) levels of acceleration using human subjects.

REVERSAL TESTS. A replica F111 seat was mounted on a rig allowing movement around a horizontal axis passing through the middle of the seat back. Three subjects, one from the mid point, and one from each of the extremes of pilot size range were seated in the F111 seat and either the American or the British harness was fastened and adjusted. The position of the top of the subject's head relative to the seat was measured on a vertical scale, then the subject was inverted and the head position remeasured. The difference in the two measurements gave the amount of vertical movement allowed by the harness under the influence of negative G.

A measure of the restraint in the lateral plane was similarly obtained by determining the movement of the points of the shoulders when the seat and subject were tilted on their sides.

With similar shoulder strap tensions, mean vertical movements on inversion of 3 inches were observed with the American harness, and 2/3 inch with the British alternative. Mean lateral shoulder movements obtained with the American harness were 3¼ inches whilst movements of 2 inches (right) and 2¼ inches (left) were obtained with the British harness.

SWING RIG TESTS. In order to assess and compare the restraint afforded by both harnesses at higher levels of acceleration, five subjects of varying body size wearing F111 flying clothing, were exposed to simulated crash forces in the forward, lateral and 45° forward and to the left planes. Deceleration was produced by swinging the subject in a frame containing a replica of an F111 seat suspended from the roof of a laboratory and then arresting the swing by cables. The plane of deceleration was varied by altering the suspension of the frame and the seat relative to the axis of the swing. The magnitude and rate of rise of the imposed deceleration were varied by altering the lateral displacement of the frame before release. Throughout the tests, continuous measurements were made of acceleration, harness strap loads, and head and shoulder movements. The shoulder straps of both harnesses were tensioned before the deceleration by weights to simulate retraction by the powered inertia reel. High speed cine photography was taken of head movement throughout the deceleration phase to analyse and measure the head movement in greater detail. A mock-up of the cockpit canopy of the F111 was placed beside the seat to determine the likelihood of collision between subject's helmet and the cockpit canopy during deceleration. Comments on restraint and discomfort were recorded throughout the tests.

One hundred and twenty-seven human deceleration tests were conducted using this apparatus. The maximum peak deceleration recorded was 17.7 G in the lateral plane, 14 G in the forward plane and 8.2 G in the 45° plane. The British harness was considered more comfortable throughout the experiments by all the subjects. Most adverse comment was centred on the American harness when the shoulder straps were tightened, simulating the powered inertia reel. This caused pain in the back and chest and breathing was difficult. These symptoms were not reported with the British harness similarly tensioned. There was little difference between the shoulder movements permitted by either harness, but the British harness allowed less head movement. Contacts between helmet and canopy took place twice with each harness with the same subject but he was unaware of these. Thus, under similar conditions of deceleration, the two harnesses performed satisfactorily, with the British harness, as judged by head movement, marginally better.

The harness strap loads were measured by strain gauges. The loads in the straps of the British harness were no greater than those observed in the American harness at similar peak decelerations. However, the negative-G strap carried high loads (900 lb at 10 G) and requires a strong attachment to the F111 seat. Modifications to the seat are also required to attach the crossed shoulder straps.

CONCLUSION

At low levels of acceleration the British harness gives better restraint than the American harness. At higher levels, the restraint provided by the more complex American harness is no better than that provided by the simpler British alternative, and the latter causes less discomfort. In addition, the British harness has notable operational advantages. It can accommodate safely all sizes of aircrew and the buckles allow tensioning of all the straps when required. The one point

fixation simplifies the harness and hastens emergency egress. The assessments have shown that the British harness has distinct advantages over the American system and is a very suitable alternative. The British version has now been accepted as a replacement for the American harness in all F111 aircraft.

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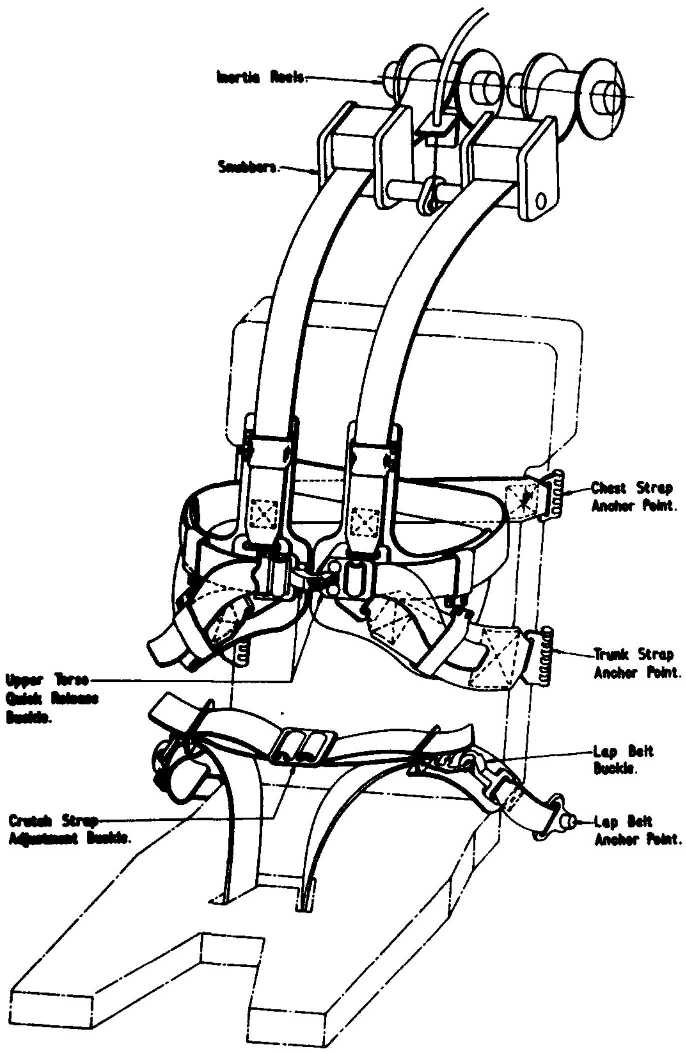

FIG. 1. U.S.A.F. F111 HARNESS RESTRAINT SYSTEM

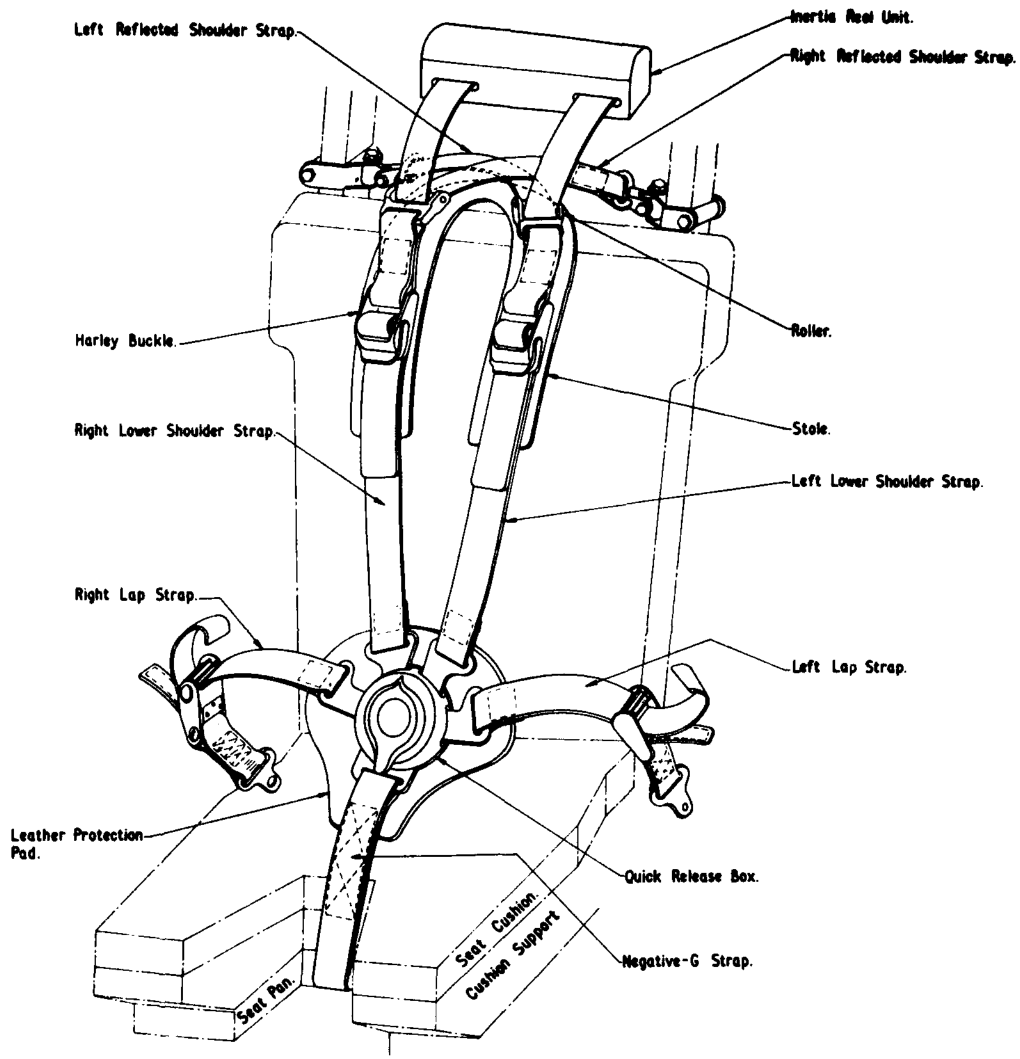

FIG. 2. R.A.F. I.A.M. F111 HARNESS RESTRAINT SYSTEM

PHYSIOLOGICAL ASSESSMENT OF AIRCREW PROTECTIVE SUIT SYSTEMS UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

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SUMMARY

The protection of aircrew personnel under adverse environmental conditions encountered during the overall mission and potential emergency is a problem of continuing importance. Different protective suit systems (PSS) have been designed to satisfy requirements for environmental protection in the maintenance of a physiologically tolerable level of thermal equilibrium in the in-flight condition as well as in the emergency condition. The problem is further complicated by the very nature of the aircraft (helicopter, patrol, fighter, and attack), each endowed with peculiar conditioning systems and mission profiles. Among the PSS considered in this survey are the USN MK5A suit assembly, the divers' wet suit (WS), and a polyvinylchloride suit (PVC). Simulated environments of extreme cold, both dry (-40°F temperature) and immersion cold (32°F water temperature), and moderate heat were induced in the physiological assessment of the various PSS. The adequacy of the protective suits under different conditions of exposure was based on measures of body temperature, heart rate, and weight loss.

THE PROTECTION of aircrew personnel under adverse environmental conditions encountered during the overall mission and potential emergency is a problem of continuing importance. It is axiomatic, therefore, that the pilot and aircrewmen must be equipped with protective suit systems (PSS) which allow for the successful accomplishment of their mission in the light of environmental variability presented during the entire flight phase; at the same time, the PSS must be designed to supply an adequate level of thermal protection during the potential emergency phase of flight in which the extremes of environmental variability are possibly encountered. The problem of thermal protection is further complicated by the very nature of the aircraft, e.g., fighter vs. patrol, each endowed with particular characteristics of supporting thermal equipment and mission profiles affecting such variables as time-in-flight, distance, and terrain. Coupled with the known elements of environmental variability and mission characteristics of the aircraft is the indefinable element of pilot and aircrew acceptability. As a consequence of this expression of acceptability, an aircrew philosophy has occasionally expressed itself in terms of a rather loose interpretation of the components of a designed PSS and, in some instances of extreme environmental exposure, in a loss of aircrew personnel.

Different PSS have been designed to satisfy certain requirements for environmental protection in the maintenance of a physiologically tolerable level of thermal equilibrium in the in-flight condition as well as in the emergency situation. The purpose of this study is to describe the physiological assessment of various PSS at the Aerospace Crew Equipment Department, Naval Air Development Center, toward the attainment of an ideal protective suit configuration for aircrew personnel exposed to different environmental conditions of both heat and cold.

METHODOLOGY

In the assessment of the various PSS considered in this investigation, the methodological approach follows a general procedure. The subjects are equipped with appropriate physiological sensors in the measurement of body temperature and heart rate. Under certain environmental conditions wherein weight losses are of interest, the subjects are weighed nude and fully equipped, before and after the experimental treatment in order to determine total and evaporative weight losses. The subjects are then equipped with the suit system under consideration and exposed to the environmental conditions for either a fixed period of time or until definite physiological endpoints are attained. In the cold environment, skin temperatures of 8-10°C and/or rectal or deep body temperatures of 35°C represent a physiological state dictating the termination of the run; in the warm environment, abortion of the run is indicated by the attainment of a rectal temperature of 39°C and/or heart rate of 140 B/min for sedentary subjects or of 180 B/min for exercising subjects. Body temperatures, sensed by means of thermocouples or thermistors, include rectal temperature and skin temperatures of different parts of the body. The different measures of skin temperature are weighted according to the area sensed and then summed to give a measure of mean weighted skin temperature (MWST).

The environmental conditions under which the different PSS are assessed for this study range from an extreme dry cold of -40°C temperature to a moderately warm environment of 46°C temperature. For test programs involving the warm environment, ventilating air is supplied, if the PSS allows for suit ventilation, at different flow rates and ventilating temperatures. In programs involving the water-cooled suit (WCS), the temperature and flow of water are noted in the discussion of results. The range of environmental testing also includes cold water immersion (0°C), with and without life raft boarding, and a wind velocity of 20 MPH.

The suit systems considered in this survey are as follows:

1. USN MK5A Suit Assembly
2. Divers' Wet Suit
3. Polyvinylchloride Suit
4. ACED Suit-Raft Assembly
5. Water-Cooled Suit

The MK5A assembly is essentially composed of a ventilating-insulating liner over which is worn an impermeable outer suit of neoprene-impregnated fabric. With appropriate neck and wrist seals and a bootie extension of neoprene rubber, it is designed to be water-tight. The divers' wet suit is composed of 3/16" foam rubber and modified by the incorporation of torso-restricted and full-length ventilation harnesses. The polyvinylchloride suit is composed of 1/8 - 3/16" foam integrated with an outer suit comparable to an ordinary flight suit. It is a rather loose fitting suit and, with Velcro-wrapped wrists and ankles and open-neck, represents a minimal effort in delimiting the influx of water in tests involving water-immersion.

The ACED suit-raft assembly is a system combining minimal suit protection and a one-man raft with inflatable hood and floor. The suit system is composed of an insulating underwear (RHOVYL), an intermediate USAF liner, and an outer impermeable garment. With neck and wrist seals and a water-proof entrance zipper, water integrity is maintained.

The water-cooled suits used in this work are of two types, depending on the extent of body coverage: (1) torso length as available through a commercial developer (Hamilton-Standard); and (2) full length, thus allowing for full coverage of the body with water distributing tubes except for the hands, feet, and head. Portable and fixed sources of water controllable in regard to temperature and flow are used in conjunction with water-cooled suits.

RESULTS

USN MK5A SUIT ASSEMBLY. The MK5A suit assembly was extensively investigated as a PSS in both hot and cold environments and under conditions of cold water immersion. Prior to the development of the MK5A, the PSS for aircrew personnel was the MK4 suit assembly (VAPOTEX) which featured an outer suit of material capable of transport of water vapor from the body but impermeable to water in the case of immersion. Thermally, the MK5A allowed for an equivalent level of insulation while affording the capability of positive ventilation for heat dissipating purposes.

In a study comparing the MK4, the MK5A unventilated, and the MK5A assembly ventilated, the advantages of a ventilating system in terms of body temperature and weight loss are observed (14). The results of this investigation are presented in Table I. Under the conditions noted, it can be seen that the MK5A assembly in the ventilated state effectively reduced total weight loss, of which the greater portion is evaporated, and maintained body temperatures at more comfortable levels. Rectal temperature was only slightly affected by the experimental treatment during the fixed 2-hour period of exposure.

The MK5A was also evaluated in extreme dry cold environments (-40°C) and under conditions of immersion-flotation and immersion followed by life-raft boarding in a study including the MK4 assembly and the USN MK-IV Full Pressure Suit (13). The results of this investigation are presented in Table II. Under the conditions noted, the near equivalence of the MK5A to the MK4 in terms of the level of thermal protection can be seen.

DIVERS' WET SUIT. In a study designed to evaluate the wet suit (unmodified) as a potential substitute for the MK5A suit assembly, it was found that temperature responses of subjects exposed to a cold environment (dry and immersion) indicated a level comparable to the existing protective suit assemblies (11). For the 2-minute immersion followed by life-raft boarding in water temperature of 32°F, air temperature 20°F, and wind velocity 20 MPH, tests were terminated after 2-3 hours. In a state of constant immersion-flotation in 32°F water, subjects generally tolerated an exposure of approximately one hour. In the extreme dry cold environment of -40°F, subjects tolerated an exposure of one hour with observed exposure times of 1.5 hours in an ambient environment of 0°F and 2.0 hours in an ambient environment of 20°F. In moderately warm environments of 80°F and above, skin temperatures approached core temperature in 4-5 hours with resulting excessive heat storage. In an ambient environment of 100°F, levels of MWST and rectal temperature reached in 2.5 to 3 hours at an ambient of 90°F were attained in a matter of 100 minutes in the sedentary subject.

The physiological effects of wearing the unmodified wet suit in moderately warm environments prompted the development of a wet suit modified by the incorporation of a full length ventilating harness. The results of a study (12) using the ventilated wet suit in different ambient environments, with varying flow rate and temperature of ventilating air for a fixed period of two hours, are presented in Tables III and IV. In an ambient temperature of 40.6°C, increase in MWST was appreciably greater when the ventilating temperature was maintained at 32.2°C than that effected by a ventilating temperature of 23.9°C. While an appreciable difference in total weight loss was observed when ventilating with the two levels of air temperature, the evaporating efficiency ranged between 75-85% for all tests. In an ambient environment of 32.2°C, similar changes in MWST were noted using the identical levels of flow rate and temperature of the ventilating air. While total weight loss was of the order of 200 gms, evaporating efficiency ranged between 66-83% at the two levels of flow rate (300 and 150 LPM).

POLYVINYLCHLORIDE SUIT (PVC SUIT). The PVC suit (1/8") was used in a limited test program in simulated environments of dry cold, cold water immersion, and moderately warm temperatures. In a 0°F temperature environment, subjects tolerated the exposure for approximately 70 minutes with final MWST reaching a level of 28.0°C; rectal temperature was relatively unaffected. At -40°F temperatures, a tolerance endpoint was attained in 35 minutes with final MWST of 24.5°C; rectal temperature decreased by 0.7°C from initial levels. In immersion tests with water temperatures at 32°F, air temperature 20°F, and wind velocity 20 MPH, results indicate that tolerance times varied between 35 and 60 minutes. Severe levels of MWST (21.0°C and 18.5°C respectively) were reached in the course of these exposures. Under conditions of 5 minutes immersion followed by raft boarding, subjects tolerated the exposure for approximately 70 minutes, at the end of which time MWST had decreased to a level of 25.0°C. Under less extreme conditions of 45°F water and 40°F air temperatures and a wind velocity of 20 MPH, subjects wearing a close-fitting 3/16" PVC suit tolerated the exposure for approximately 2 hours, 30 minutes. At this time, foot temperatures had dropped to 10°C, while MWST remainted at a level of approximately 28°C and rectal temperature at 37.4°C. In warm exposures, results indicate that for the sedentary subject in a 90°F ambient, physiological endpoints regarding heart rate are attained after 2.5 hours; in a 105°F ambient, endpoints regarding both heart rate and core temperature are reached in approximately 1.5 hours.

ACED SUIT-RAFT ASSEMBLY. The advantages of a combined suit and inflatable raft were indicated in a series of tests designed to assess various assemblies for submarine escape in an extreme cold water environment. Using a suit system of RHOVYL underwear, USAF liner and a loose-fitting, impermeable outer suit and a one-man raft with inflatable floor and canopy, the duration of exposure to 29°F water temperature, 10°F air temperature, and 20 MPH wind velocity was of the order of 8 hours following a 3-minute period of immersion prior to raft boarding. Foot temperatures at the end of the exposure reached predetermined cut-off levels (46-50°F) with core temperature rapidly approaching endpoint levels of 95°F. Using the same suit configuration and inflatable raft, an exposure time of 24 hours was reached in an environment of 44°F water temperature, 32°F air temperature, and a wind velocity of 20 MPH. During this time, no food or water was made available to the subject. At the end of the exposure, core temperature and surface skin temperatures were at levels well above the pre-established endpoints.

WATER-COOLED SUIT (WCS). The effectiveness of a full length WCS (NASA Model LCG-1) in providing thermal protection under heat stress conditions as compared to conventional underwear was determined in three subjects at rest and excercising at a level of 800 BTU/hr. Water was supplied at a flow of 200 lbs/hr and the inlet temperature was maintained at 81°F. Dry bulb temperature in the test chamber was kept at 95°F with a dew point temperature of 86°F. While all subjects tolerated the 3-hour exposure period, physiological advantages in terms of body temperature and heart rate were observed when the WCS system was used. In tests wherein the dew point temperature was raised to 91°F, all other conditions being equal, two of the three exercising subjects wearing the conventional underwear were removed from the test environment before the completion of the three-hour test because of heat strain, as evidenced by high pulse rates and rectal temperatures. Under these conditions, the subjects equipped with water cooling completed the prescribed exposure period.

A current program involving subjects wearing a full length WCS in conjunction with a Gemini-type full pressure suit is designed to determine the physiological responses during moderate (2000 BTU/hr) and severe exercise (3500 BTU/hr) according to a prescribed work profile which is of special interest for space operations. Water is introduced at the rate of 240 lbs/hr and at an inlet temperature of 45°F; ventilating air is introduced at a flow of 8 CFM and at a temperature of 75°F. The work profile extends for a fixed period of one hour and the tests are conducted in a normal room environment (72-75°F temperature). Preliminary observations indicate elevated heart rate and rectal temperature during the middle third of the one-hour period, this segment of time being the period in which the work rate is increased to 3000 or to 35000 BTU/hr, depending on the initial work levels imposed (2000 or 2500 BTU/hr). In the final third of the one-hour test, treadmill conditions are changed so that work loads approximate those imposed initially.

DISCUSSION

The problem of thermal protection for aircrewmembers is a complex one involving the multiple interactions of man in the aircraft environment as well as man in the potential emergency environment. With the wide range of classes of aircraft, each entrusted to particular missions and each variously equipped with different cockpit or personal ventilating conditioning capabilities, it is little wonder that the concept of the ideal, single-issue protective suit system has fallen short of its ultimate objective. As stated by researchers in the field of environmental physiology, no single suit system can supply that level of comfort required for military flight and at the same time supply the necessary protection in the emergency environment of extreme dry cold or cold water immersion.

With the range of PSS subjected to physiological evaluation in this laboratory and in the case of other suit systems tested in different research areas, some answer making use of the inflatable life raft as an integral part of the overall system becomes apparent. Two possibilities are suggested: (1) a PSS for the extreme environment in the form of a MK5A dry suit in combination with a raft with inflatable floor and canopy; and (2) a PSS of lesser overall insulation for the intermediate environment under the same raft conditions. In either case, it would appear that the totally inflatable life raft is an integral link in the extension of survival and recovery times. This fact has been demonstrated in the work reported wherein actual exposures of up to 8 hours duration using a moderate level of insulation have been attained in 0°C water.

Significantly, the work of Hall et all (5) has demonstrated, on the basis of thermal insulation with the copper manikin as the responsive subject, the potential increase of protection in life raft exposures by the use of a survival heater with propane as fuel, and by the use of infrared reflective plastic material.

All suits reported on in the course of this program, namely, the MK5A exposure suit assembly, the divers' wet suit, and the polyvinylchloride suit possess some merit as PSS. Each suit system, however, must be considered in view of mission requirements, involving the nature of the aircraft, and the anticipated environmental conditions, both during flight and in the event of emergency exposure. It is considered that the protective characteristics of the above-mentioned suit systems would be substantially increased by the integrated use of the totally inflatable life raft in the extreme cold water environment, if the maintenance of relative thermal comfort during the flight phase can be assured by appropriate thermal conditioning.

The severe physiological effects of cold water immersion, despite exposure suit protection, has not only been indicated by the work reported herein but more especially emphasized in the works of Beckman (1), (2), Milan (9), and Molnar (10). The problem of extremity protection and severe hypothermia was also emphasized by Cannon (4) who observed that subjects were incapable of helping themselves after 20 minutes in 4°C water. It should be noted that the cold stress imposed on laboratory subjects may not at all compare to the actual combined stress of extreme temperature, extended duration, execution of recovery maneuvers, psychophysiological impairment, and, most important of all, the very real possibility of even limited injury, all incurred to some degree in the course of the emergency event. While we are prone to extend the actual exposure time attained in the simulated environment and based on some physiological measure for extimates of survival, the above-mentioned elements operative in the real emergency environment may, in fact reduce experimental times in the determination of survival periods.

In the broad treatment of PSS as reported herein, the tendency was to gloss over the consideration of special areas of the body particularly affected by the cold environment. Reference here is made to extremity protection. Generally, the protection afforded these areas in our work has been in the form of materials insulation, e.g., wool socks and insulated flying boots for the feet and wool gloves and exposure suit mittens for the hands. In the main, these elements of thermal protection are not completely satisfactory in that experimental runs have been terminated by reason of extremity temperatures (8-10°C) and not by reason of body temperatures as influenced by the thermal characteristics of the overall suit system per se. Conservative temperature endpoints are used in laboratory exposures in order to insure against the possibility of tissue damage and at the same time assure the return of the subject in trials on a scheduled basis. The fact remains that some dynamic method such as electrical or chemical heating must be explored, since materials insulation alone has not been effective in maintaining the extremities at temperature levels supportive of extended protection.

In a consideration of PSS in high ambient temperatures, the water-cooled suit has demonstrated its effectiveness in both resting and exercising subjects in the limited programs herein reported and in more extensive programs reported elsewhere (3), (15). In the absence of a water conditioning system fixed within the aircraft, the WCS making use of portable conditioning units represent a possible solution to the problem of personnel protection. Making use of a portable liquid cooling system using wet ice, the field effectiveness and pilot acceptability of a water-cooled vest were determined by Hatlelid et al (6) during simulated and actual tropical field conditions with cockpit temperatures ranging between 75-115°F and relative humidity between 30-80%. The metabolic heat sink was provided by cooled water pumped in a closed loop from ice chest to the garment. Using this system in our laboratory, findings in terms of the maintenance of relative thermal comfort and of reduced sweat loss in ambient temperature of 115°F for 2-4 hours were corroborated. The arms and legs, not receiving the advantages of water cooling with the vest-type suit, attained temperatures which approached core temperature by the end of the trial. In order to reduce size, weight, and to extend the time of effective cooling, attempts in our laboratory have been in the direction of a portable system making use of dry ice. Interim models have indicated the feasibility of such a system for the alleviation of thermal stress in terms of sweat loss, body temperature, and heart rate.

The possibility of automatic control of water temperature has been shown in a study (8) based on a new fluid technology in which fluid streams of considerable momentum are diverted by relatively low energy flows. Fluidic techniques are also employed in the use of skin temperature as an input signal to the control system. The overall system is undergoing modification in the development of a multi-zoned, automatically controlled liquid cooling capability.

While most attention has been centered on water conditioning for high temperature protection, the conventional air ventilation systems have received some additional consideration. In a study (7) designed to make maximal use of circulating cooling gases, ventilated cooling principles have been employed on a simulated sweating arm using flows up to 1.5 ft^3/min and skin-to-shield separations of 0.4, 0.2, and 0.1 inches. The mixing of warm moist air from the skin and cool, dry ventilating air was observed using Schlieren optics. By the insertion of baffles through the shield wall and by introducing fresh ventilating air at 6-inch intervals along the sweating arm, evaporative and total cooling capabilities were approximately doubled.

It would appear, therefore, that the ultimate answer to the problem of PSS for aircrewmembers depends on such studies as represented by the multi-zoned, automatically controlled water conditioning systems and concomitantly on studies concerned with more effective means of body temperature control using ventilated clothing in the in-flight environment. For the emergency environment of dry cold and cold water immersion, a solution depends on studies concerned with auxiliary extremity protection and with an increase in the thermal protective properties of the raft system.

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TABLE I. PHYSIOLOGICAL COMPARISON OF VENTILATED AND NON-VENTILATED ANTI-EXPOSURE SUITS

SUIT	AMB. TEMP. (°C)	TOTAL WEIGHT LOSS (gm)	% WEIGHT DEFICIT	RECTAL TEMP. (FINAL) (°C)	MEAN SKIN TEMP. (FINAL) (°C)
Unventilated Impermeable	15.5	241	0.27	37.0	33.6
	26.6	604	0.67	37.5	36.2
	37.7	1058	1.19	37.6	37.2
Unventilated Permeable	15.5	210	0.23	37.1	33.8
	26.6	600	0.67	37.6	34.7
	37.7	692	0.67	37.7	35.5
Ventilated Impermeable	15.5	162	0.18	36.6	31.9
	26.6	298	0.33	36.8	33.5
	37.7	553	0.62	37.0	34.4

TABLE II. BODY TEMPERATURES AND EXPOSURE TIMES OF SUBJECTS WEARING PROTECTIVE SUITS IN -6.6°C AIR AND 0°C WATER

CONDITION	PROTECTIVE SUIT ASSEMBLY	DURATION (HR:MIN)	RECTAL TEMP. (FINAL) (°C)	MEAN SKIN TEMP. (FINAL) (°C)
1. Immersion and Flotation	MK4	0:52	37.7	27.3
	MK5	0:58	37.4	28.0
2. Same as 1 with Life Raft Boarding	MK4	4:00	36.3	28.4
	MK5	3:08	36.2	27.0
3. Same as 2 plus Wind Velocity (20 MPH)	MK4	3:00	37.0	27.6
	MK5	2:18	37.3	28.2

TABLE III. EFFECTS OF VENTILATION ON BODY TEMPERATURE, WEIGHT LOSS, AND HEART RATE IN A 40.6°C (105°F) TEMPERATURE ENVIRONMENT USING THE VWS (ACED)

T_v (°C)	FLOW RATE (LPM)	MWST (°C)	T_r (°C)	TWL (GMS)	% EVAP.	HR (B/MIN)
32.2	300	Δ1.55+	Δ0.4+	552	77.5	Δ7+
	150	Δ2.53+	Δ0.8+	560	75.0	Δ13+
23.9	300	Δ1.28+	Δ0.1-	274	84.0	Δ2-
	150	Δ1.33+	Δ0.0	488	80.0	Δ5+

TABLE IV. EFFECTS OF VENTILATION ON BODY TEMPERATURE, WEIGHT LOSS, AND HEART RATE IN A 32.2°C (90°F) TEMPERATURE ENVIRONMENT USING THE VWS (ACED)

T_v (°C)	FLOW RATE (LPM)	MWST (°C)	T_r (°C)	TWL (GMS)	% EVAP.	HR (B/MIN)
32.2	300	Δ1.20+	Δ0.1-	262	82.7	Δ3-
	150	Δ1.71+	Δ0.1+	270	74.0	Δ1-
23.9	300	Δ1.06+	Δ0.8-	200	71.5	Δ7-
	150	Δ1.00+	Δ0.1+	198	66.0	Δ2+

THE WATER COOLED SUIT

by

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SUMMARY

Some literature on water cooled garments is reviewed. Several problems still await solution, of these the ability of skin sensation to guide the correct selection of inlet temperature to maintain thermal balance, and the effect of vasoconstriction on the performance of the suit are discussed in detail.

THE CONCEPT OF personal cooling for aviators developed significantly following the advent of gas turbine propulsion. In practice air has always been used as the cooling agent. During recent years, however, great interest has been shown in water cooling systems. This is because the use of water as a cooling agent theoretically reduces the pumping power required by a thousandfold due to the higher specific heat of water and the improved mechanical efficiencies of pumping a liquid rather than a gas, (Burton and Collier, 1964 and Crocker et al, 1964). Cooling is effected by a process of heat conduction. Cold water passing over skin in a hot environment extracts heat entering the skin together with the metabolic heat load.

THE DEVELOPMENT OF BRITISH WATER COOLED SUITS

Burton and Collier designed some garments to test the efficiencies of a water cooling system. They first described their suits in 1964. These original suits consisted of a stretch material through which was threaded a network of small water pipes held in direct contact with the skin. Using these suits they developed a general hypothesis for personal water cooling, (Burton and Collier, Jan 1965). They gave performance equations as follows:

$$Q = \dot{m}Cpe\,(33 - T_{IN}) \qquad (1)$$

$$T_{IN} = 33 - Q/\dot{m}Cpe \qquad (2)$$

$$e = 1 - \exp\,(-AU/\dot{m}Cp) \qquad (3)$$

Where Q = The cooling rate Kcal/hr

$\dot{m}$ = Mass flow Kgm/hr

Cp = Specific heat Kcal/gm/°C

T_{IN} = Inlet temperature °C

e = Effectiveness of the suit as a heat exchanger = $\dfrac{T_{OUT} - T_{IN}}{33 - T_{IN}}$

T_{OUT} = Outlet temperature from the suit °C

A = The total wetted area of the suit cm^2

U = The overall heat transfer coefficient $cal/cm^2/hr/°C$

(This last value includes components for a man's skin - the pipe material between the skin and the water in the pipes, including the outer surface of the water.)

BURTON AND COLLIER'S EQUATIONS imply that the heat extracted by the suit and the inlet temperature will be linearly related assuming constant mass flow, skin temperature and conductance. They assumed that a minimum inlet temperature of 0°C would be practicable, and from this predicted that the maximum amount of cooling available from their suit would be approximately 480 Kcal/hr. Burton and Collier also tested 20 subjects in one climate and at one suit water flow rate to discover the range of cooling rates chosen by the subjects. They found an unexpectedly wide choice of inlet temperatures and, hence, cooling rates, and suggested that this might be due to differing thermal states existing before the experiments or to incorrect interpretation of sensory information from the skin. Should the latter interpretation be correct, and it is certainly a possibility in view of the abnormal distribution of skin temperature caused by the proximity of cold water pipes, it may prove a serious disadvantage for this system of personal conditioning.

Allan (May 1966 and Feb 1966) using a similar suit redesigned to remove unpleasantly cold areas showed that the normal skin temperature distribution associated with comfort (Kerslake, 1964) was not to be found. The mean skin temperature fell progressively as the environmental temperature increased. The abnormal distribution was most noticeable at the coldest inlets. Probably because of an intolerance to these low skin temperatures his subjects allowed their body temperatures to rise. The extent to which this might effect their performance whilst flying could not be assessed. He also found a non linear relationship between the chosen inlet temperature and the heat extraction rate, and suggested that there were changes in skin heat conductance with low inlet temperatures.

In another series of experiments these early water cooled suits were found to be effective in cooling three subjects in several warm/hot climates (Clifford, 1964).

During this experimental work numerous mechanical difficulties had been encountered which made the suits unreliable. These problems consisted mainly of snagging, kinking and brittleness in the small polyvinyl pipes and some aspects of the problems were investigated, (Collier, 1965). A new series of garments were designed to overcome these problems by having the small distribution pipes enclosed in fabric tunnels. It was expected that a layer of material between the skin and the water pipes would reduce the effectiveness of the suit. Two harness sizes were developed. The first similar in length to the original suits having 65 metres of distribution pipes and a second having 130 metres of distribution pipes which it was hoped would permit the use of higher inlet temperatures. The tunnels were either mounted next to the skin (internally) or away from it

(externally). Suits were also designed using two layers of stretch material. These suits were so constructed that the pipes were lying in tunnels between the two layers of the suit.

THE EXTERNALLY TUNNELLED SUIT was first described (Burton and Collier, July 1965) with 65 metres of tubing. They concluded that although comfort, ease of dressing and resistance to kinking had been improved, this had been at the expense of thermal performance. The range of climates in which the suit could be expected to maintain thermal balance was reduced. This type of suit, under lightweight flying clothing, was tested in Libya (Collier and Williams, 1965) and found subjectively satisfactory in dry climates up to 52°C. However it was noted that the suit was very warm when unconditioned and difficult to take on and off if the suit was damp or if the subject was sweating. The suit was also found to be liable to leaks.

The effects of humidity were investigated on an externally tunnelled 65 metre pipe harness suit, (Allan, July 1966). He found no significant difference in the choice of inlet temperature between dry and humid environments, but again a wide variation in choice of inlet temperature. There was however a significant increase in the overall heat extracted in the humid environments and he suggested that this was due to the condensation of water vapour on the cold pipes which also increased the amount of cooling required by the conditioning system. His subjects again failed to maintain thermal balance and allowed their body temperature to rise by up to 1°C with an accompanying increase in sweating. He thought that subjects preferred to allow their body temperature to rise rather than lower the inlet temperature still further and suggested that this may have been due to overcooling of those areas protected from the environment in a seated pilot, that is the buttocks and back.

FLIGHT TRIALS were carried out using a single seat Lightning aircraft. The following types of water cooled suit were used during the trials:

1. An externally tunnelled water cooled suit with a 65 metre pipe harness.

2. An internally tunnelled water cooled suit with a 65 metre pipe harness.

3. A double-layered water cooled suit with a 130 metre pipe harness.

The Flight Trial report (Dover, 1967) made no clear distinction in the merits of individual suits. The suits used, on subjective grounds, appeared to be satisfactory cooling garments in aircraft cabin temperatures up to 40°C. Dover suggested that on purely engineering grounds, it was unlikely that an inlet temperature lower than 2°C would be practicable because of heat leakage between the conditioning unit and the suit. In this particular trial he suggested that the available cooling had been reduced to as little as 70% of that leaving the conditioner and suggested that this would probably explain the reduction to 40°C from 52°C in the upper limit of climate in which the suits had been found subjectively acceptable. He also suggested that one way of overcoming this would be the use of anti-freeze in the water and vapour cycle refrigerator units. The effect, of several anti-freeze solutions, on the thermodynamic efficiency of water cooled suits was investigated, (Camp, 1967). He demonstrated that the choice of antifreeze solution was dependent on whether the system was to be lowered to -40°C or -20°C. He showed that the reduced specific heat of the water mixture tested would not greatly reduce the efficiency of the suits and add to the pumping power required. However no work has been carried out on the physiological effect of very cold liquids passing through water cooled suits, and it is likely they would be unacceptable. These suits also proved liable to leaks and were found to be very warm when unconditioned.

Field trials of similar suits were carried out in the Far East (Williams et al, 1966), and similar maintenance difficulties were found. The warm nature of the garments when worn unconditioned was also confirmed.

In an endeavour to further examine the role of changes in skin conductance a series of experiments were undertaken by the author. The design of these experiments assumed that the non linear relationship of inlet temperature and heat extraction, found previously, was due to vasoconstriction occurring either locally under cold pipes or more generally throughout the skin. It was hoped to show that skin heat conductance fell at low inlet temperatures. The suit used was a double layered 130 metre pipe harness suit, and the experimental approach different in that the three subjects did not choose their inlet temperatures. Each subject was tested at several fixed inlet temperatures in two climates of 50°C dry bulb. One climate was dry (wet bulb temperature 23°C), and the other humid (wet bulb temperature 36°C). By not allowing the subjects to choose their own inlet temperature it was hoped to reduce the variation in the relationship between inlet temperature and heat extraction so that any change in this relationship would be seen more easily. However the author was unable to demonstrate a non linearity between inlet temperature and heat extraction but showed that it was similar in range to that found by Burton and Collier in their series of twenty subjects (fig 14, Burton and Collier, Jan 1965). It should be emphasised that these experiments were done using a double layered suit which is likely to cause a less marked effect on skin temperature than was found by Allan (May 1966) using the original suits, but similar to his results using the first tunnelled suits when he did not confirm his original curved relationship between inlet temperature and heat extraction (Allan, 1966).

It appears from American work that similar problems to those noted in British work have been encountered by several teams of workers developing cooling systems for the American Forces and the Space Programme. Webb and Annis (1967) have shown that vasoconstriction occurs at very low inlet temperatures in the particular conditions of their experiments. These were quite different to the

British experiments and involved exercising men in a situation where metabolic heat had to be removed. Their suit allows a much greater contact as in between water pipes and skin than in any British suit. With this more efficient suit they also found that subjective control of inlet temperature was not satisfactory in maintaining thermal equilibrium during strenuous exercise. Over cooling resulted in vasoconstriction which permitted a further fall in skin temperature from its expected subnormal level. However when subjects had too low an inlet temperature, (were over-cooled), their rectal temperatures rose and the heat removed by the suit became much less than the heat produced by the exercise. But as expected, under cooling was accompanied by increases in rectal temperature and accompanied by sweating which made the clothing unnecessarily wet.

They considered that the appropriate control of inlet temperature during exercise was oxygen consumption. They showed that thermal equilibrium could be maintained satisfactorily at several varied exercise rates using this method.

DISCUSSION

The interest in water cooled suit systems is unlikely to wane in the foreseeable future. The system was originally investigated as a possible competitor to the air ventilated suit systems. Although there is little doubt that water cooled suits are promising cooling garments, the subjective control of this cooling appears to be more difficult than was originally anticipated.

Both British and American studies have demonstrated rises in central body temperatures (measured in mouth or rectum), when subjects have control of the inlet temperature. The similarity in findings of these experiments may suggest a similar causal mechanism. It would appear that impaired peripheral thermal sensation may be responsible. It seems likely that vasoconstriction in the skin is caused by the use of low inlet temperatures and that this may limit the performance of the suit.

Because impaired peripheral sensation may be responsible for the wide range of inlet temperatures chosen, trial results that rely solely on subjective opinion should be interpreted with caution.

Whether or not the water cooled suit will ultimately prove to be a better solution to the problem of personal conditioning than the air ventilated suit systems is not clear at the present time. Improvements to the suit may well overcome the difficulties of control and remove the risk of undetected rises of central body temperature, but its ultimate success or failure is more likely to depend upon the performance of the conditioning equipment both in the aircraft and on the ground.

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FLASHBLINDNESS PROTECTION SYSTEM

by

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SUMMARY

The inability to provide satisfactory protection from high intensity flashes of light by use of fixed density goggles without at the same time severely reducing the light available for performance of visual tasks has led to a search for some alternative mode of protection. The ideal flashblindness protection system would be one which has an open transmission of one hundred percent, places no restriction on the field of view, immediately attenuates the light with a density just sufficient to prevent a change in vision with the onset of the flash and clears automatically as the light level is reduced. The ideal system is not in the forseeable future. The most recent development in flashblindness protection is the Navy Photometric System which provides a dynamic, indirectly actuated, automatically clearing goggle. The characteristics, advantages and disadvantages of the system are described.

FLASHBLINDNESS PROTECTION SYSTEM

Gloria T. Chisum, Ph.D.

Flashblindness, the temporary loss of useful vision following exposure to a high intensity flash of light, has been recognized as a problem for a number of years. The special, and potentially critical, significance of this problem for pilots of high performance aircraft has prompted the search for realistic methods of flashblindness protection and a large number of approaches have been considered. Some of these methods are listed in Figure 1. Of the methods listed in this table as passive, the eye blink response is too slow to prevent a prolonged change in the adaptation level of the eye following exposure to a flash of light. The eye patch provides protection from one flash since one eye is completely covered while the second eye is exposed. In addition to eye damage, the wearer of an eye patch pays the penalty of reduction of depth perception and field of view.

With one exception, the fixed filters which afforded satisfactory protection were too dense to be worn continuously. The one exception is a 1 to 2% transmitting gold-coated visor shown in Figure 2. The transmittance of this visor is highest between 510 to 520 nanometers and is least in the infrared region of the spectrum where the reflectance of the gold is highest. Vision through the visor is good when the ambient light level is high. When the ambient light level is low, as at dawn, dusk, under a dense overcast and, of course, at night, vision through the visor is too poor to be tolerated by pilots. During bright daylight, the visor does provide adequate protection.

Some of the dynamic, or automatic, methods of providing protection that have been considered are listed in the table according to the shuttering principle employed. Among those listed as mechanical, the only one which has been pursued beyond the feasibility stage is an explosively actuated lens filter, usually referred to by the acronym ELF. The ELF system is shown in Figure 3. The ELF system consists of a sensor and an explosive lens mounted on a modified APH-5 helmet combined with a small trigger and power pack which are carried on the man. The lens is shown diagrammatically in Figure 4. When the mild detonating charge, shown at the top center of the diagram, is activated following an appropriate environmental light change, a colloidal suspension of carbon is driven from its reservoir into the chamber formed by the double lens. The inner surfaces of the lenses are coated by the suspension and extremely high densities are reached within a few hundred microseconds following the occurrence of a stimulus. The wearer is then effectively blind until the lens is removed and replaced by a fresh one. A number of spare lenses must be carried by a user of this system and in addition, a secondary enclosure must be provided to afford protection while the spent lens is removed and replaced. The ELF system, therefore, is considered to be an interim method of protection until a more satisfactory system is perfected. The system does provide protection under most circumstances, but the burden placed on a user is too great to be tolerated indefinitely.

Of the various types of polarizing devices which have been proposed, all have been regarded as unacceptable for two basic reasons. The inherent transmittance of the devices in the open state is low, and the field of view through the devices is too small unless they are used in conjunction with an optical system.

A large number of chemical-molecular approaches have been proposed as solutions to the problem of eye protection. Some, such as fast-plating techniques, have not shown sufficient promise to be carried beyond feasibility studies; others, such as photochromic compounds, and triplet state enzymes, have shown sufficient promise to be pursued beyond the preliminary stages of investigation. A photochromic flashblindness protection device has been developed for the United States Navy that, although not ideal, does represent a considerable improvement over existing devices in several respects, a major one being automatic reversibility.

This device is a helmet and goggle configuration as contrasted to some other designs that have used configurations adapted to wind screen segments and optical system components. The Navy photochromic system is shown schematically in Figure 5.

The system consists of a light sensitive detector, a trigger, a power supply and the goggle. The light sensitive detector and associated circuitry are mounted on a specially modified APH-5 helmet. The response of the detector circuit to appropriate environmental light changes activates the trigger circuitry which in turn activates the discharge circuitry of the power supply to initiate the flash tube action. The result of the flash tube activation is a decrease in the transmittance of the goggle. The active material in the goggle is a small quantity of photochromic chemical in solution. The solution is clear in the unactivated state, and becomes colored when exposed to ultraviolet radiation. The solution reverts to the clear state when the ultraviolet exposure ends. Ultraviolet filters are mounted between the flash tubes and the photochromic wedge cells. When the flash tubes are activated, the visible portion of the flash tube spectral emission is absorbed and the ultraviolet portion passes through the filter to the wedge cell. The wedges distribute the ultraviolet energy through the photochromic solution uniformly so that the entire goggle area is colored to the same density. The density is not, however, spectrally uniform, or neutral. Figure 6 shows the transmission of a typical photochromic dye as it is exposed to increasing amounts of

Passive Methods

Blink Response

Eye Patch

Fixed Filters

Automatic Methods

Mechanical	Polarization	Chemical-Molecular
ELF (Explosive)	Stressed Plate	Photochromic or Phototropic Chemicals
Electro-Mechanical Goggle	Kerr Cell	Photochromic Glass
Curtain	Pockle Cell	Triplett State
Destruction of Mirror Surface		Fast-Plating
Exploding Wire		Electrolytic
		Di-Pole

Figure 1. Flashblindness Protection Methods

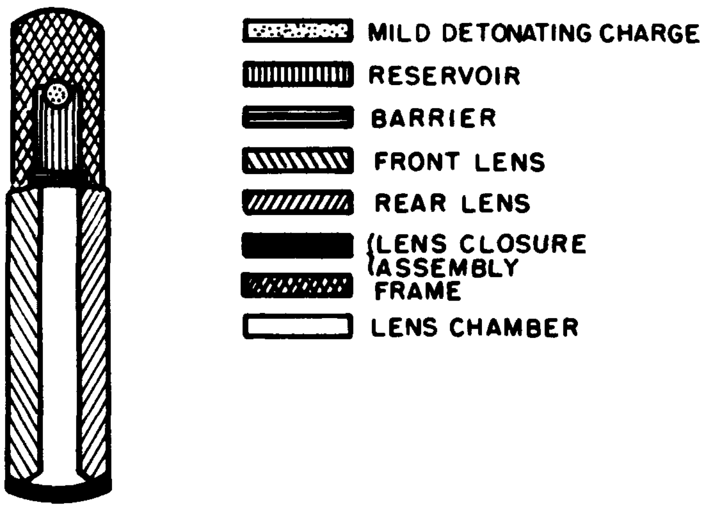

Figure 4. ELF Lens Diagram

Figure 2. Gold Coated Visor

Figure 3. ELF Flashblindness Protection System

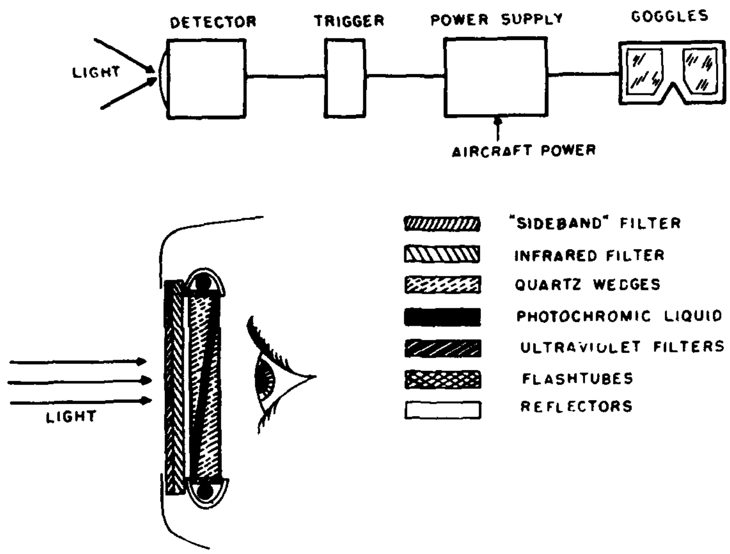

Figure 5. Photochromic Flashblindness Protection System Diagram

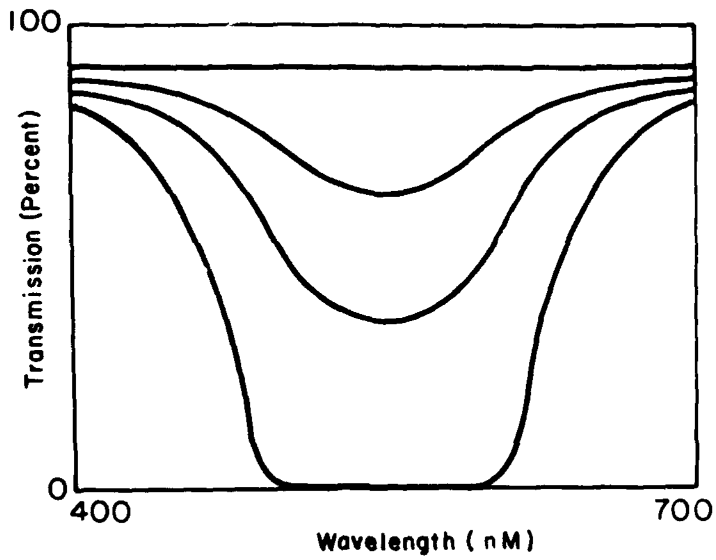

Figure 6. Transmission of a Typical Photochromic Dye

ultraviolet energy. The top line in the figure represents the transmission in the unactivated state. Each line below the top line represents the transmission following exposure to increasing intensities of ultraviolet energy. The photochromic materials develop little density in the blue and red ends of the spectrum. For this reason fixed filters have been used in the goggle to provide density in the regions in which the photochromic solution develops little density.

In the Navy goggle, the fixed filters are a blue absorbing filter and an infrared - near infrared absorbing filter shown in the diagram in front of the photochromic wedge cell. The light passes first through the two fixed filters, then through the photochromic wedge cells and then to the eyes. The result of using the fixed filters is to reduce the open transmission of the goggles to between forty and fifty percent. The spectral transmission of the goggle in the open state is shown in Figure 7. The goggle appears yellow in the unactivated or open state. The subjective effect of the selective transmission of the goggle is better visibility than would be experienced through a neutral filter of the same density because the goggle is an effective haze filter. The closed density of the goggle is a function of the sensitivity of the photochromic material, the width of its absorption band, the sideband filters, the amount of ultraviolet activating energy per unit area, and the optical configuration. There are some trade-offs which must be made regarding each of these parameters. The combination of parameters which have been selected for the Navy system is the one deemed most suitable for the purpose on the basis of flash stimulus estimates, and the eye response data which are available. Since the photochromic molecule reacts to the absorption of a quantum of ultraviolet energy within a fraction of a microsecond, the time required to close the shutter, or goggle, is dependent almost entirely upon the time required to deliver the ultraviolet energy to the photochromic cell.

The closure time, therefore, is determined by the characteristics of the electronic flash circuitry and the flash tubes. The current prototype of the system makes use of the most optimized combinations of electronic flash characteristics available. The peak density of the system, is reached within microseconds following the onset of an intense light source. The goggle clears within a few seconds following activation. The system can be operated repetitively and withstands many operations before any noticeable deterioration occurs.

The most recent prototype of the system is shown in Figure 8. Two light sensitive detectors and the trigger circuitry are located on the helmet above the goggle. The power supply must be mounted in the aircraft and receives power from the aircraft. The goggle and associated components are mounted on a movable visor attachment on the helmet.

An ideal flashblindness protection system would be one in which the open state transmission is nearly 100 per cent, which places no restriction on the field of view, which, with an increase in ambient light level, whether from a weapon flash or some other source, instantaneously attenuates the light with a density just sufficient to prevent a change in vision, which clears as the light level decreases, has an override control available to the user and which transmits maximally in the event of a power failure. Such a device is not technologically feasible at the present time. Although there are shortcomings, the photochromic system does represent a considerable improvement over previous systems in terms of the ideal system characteristics.

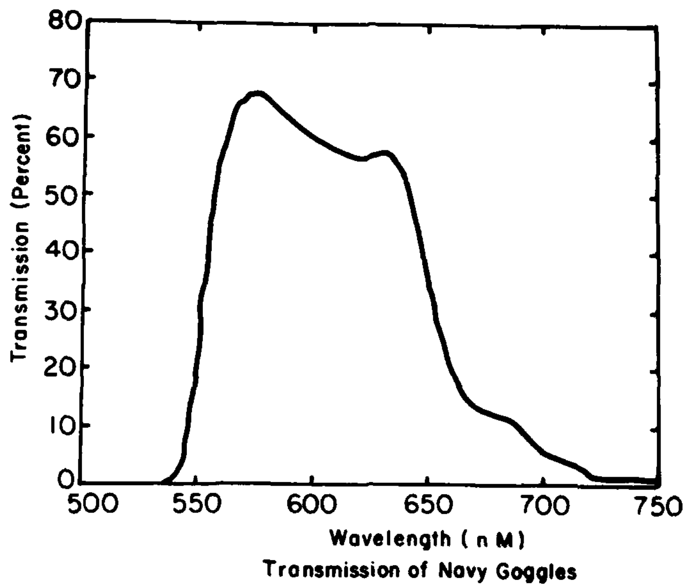

Figure 7. Spectral Transmission of the Photochromic Goggle

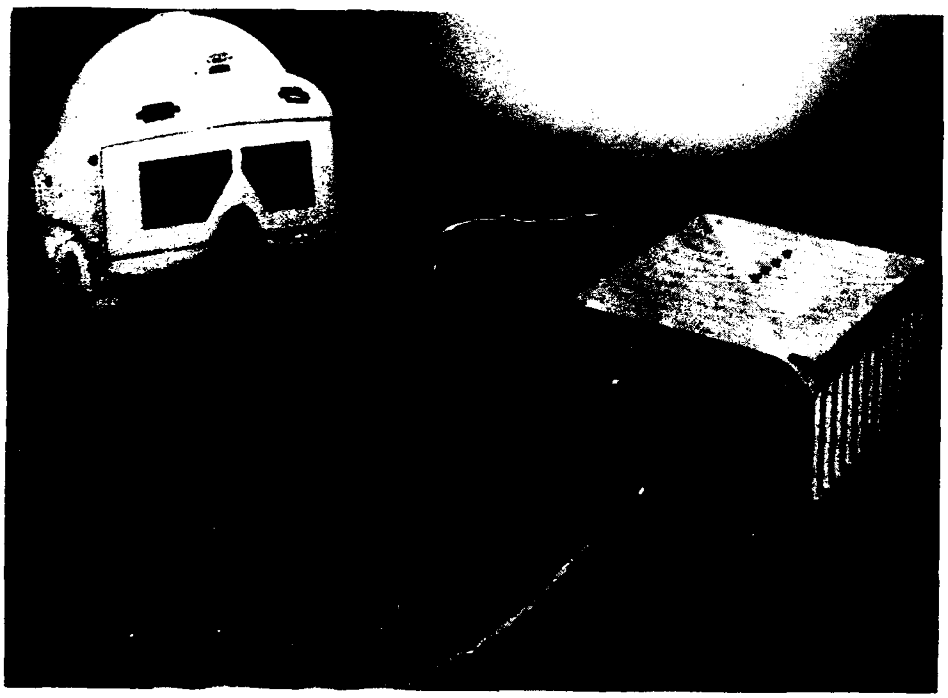

Figure 8. Photochromic Flashblindness Protection System

CARDIOVASCULAR ASPECTS OF HYPODYNAMICS

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SUMMARY

Bed rest has become accepted as a reasonable experimental model for the study of weightlessness. Changes in cardiovascular regulatory mechanisms occur after prolonged bed rest and are manifested by orthostatic intolerance and reduced work capacity.

Exposure to inactivity produces a gradual decrease in cardiac stroke volume and a rise in resting pulse rate. There is also a decrease in oxygen transport capability. These changes, combined with a decrease in plasma volume and red cell mass and a loss of skeletal muscle, produce a significant decrease in work capacity which fails to completely return during three weeks ambulation. Prevention of this deconditioning by exercise during bed rest appears to be feasible and is being studied.

Orthostatic intolerance resulting from bed rest was not obviated by restoration of plasma volume using drugs but can be obviated by exposure to lower body negative pressure during the final few days of bed rest. Decreased sympathetic nervous activity appears to be a factor in producing this intolerance but other factors may be important. Unlike the decreased work capacity, orthostatic tolerance tends to be restored within 48 to 72 hours of ambulation.

CARDIOVASCULAR ASPECTS OF HYPODYNAMICS

CARDIOVASCULAR

THE PURPOSE of the cardiovascular system (CVS) is to provide the environment necessary for cellular life and function under a variety of changing circumstances. This cellular environment is provided by an adequate exchange of gases, nutrients, electrolytes, water, enzymes, hormones and by-products of metabolism. The provision of this environment by the CVS is dependent upon the integrity of a number of integrated and inter-dependent functions.

At rest, or in basal conditions, considerable reserve is present in each function and therefore in the CVS as a whole. The system may be stressed to maximum response in a variety of ways under which circumstances a decrement in the capacity of any one function results in a decrement in the overall function. Exposure of man to orbital space flight has provided a new environment and a new stress not encountered previously, i.e. weightlessness. Added to the weightless state are other factors affecting the CVS such as psychic stress, inactivity, confinement, high-G loading, reduced atmospheric pressure, etc.

Data gathered from orbital space flight to date indicate a decrement in the CVS's ability to respond to stress. Decreased work tolerance and decreased orthostatic tolerance with a tendency to syncope has been noted on return to earth from orbital flight[5].

Water immersion for short-term study and bed rest for prolonged study have become accepted experimental models for ground-based studies of weightlessness. Changes in the cardiovascular, metabolic and musculoskeletal systems induced by bed rest simulate those observed during zero gravity. Bed rest imposes a state of inactivity and confinement inherent in the present generation of spacecraft and in addition removes the effect of gravity from the long axis of the body. A review of studies from the literature and bed rest studies in our own laboratory will be the subject of this presentation.

Upon assumption of recumbency or weightlessness, the hydrostatic pressure of the column of blood from the heart to the feet is obviated and there occurs a shift centrally of about 12% of the blood volume[18]. A diuresis of both water and sodium ensues as a result of the increased stretch receptor outflow from the central venous bed[4,9] (Figure 1). The stretch reflexes initiated by the shifted volume reduce the production of antidiuretic hormone and cause an increase in free water excretion by the kidney. The same or similar volume receptor reflexes and probably osmole receptors may decrease aldosterone secretion and therefore increase sodium excretion by the kidney[8,12]. The result is a decrease in plasma volume from 300-800 ml with an average loss of about 500 ml (Figure 2).

Red cell mass (RCM) has been shown to decrease by an average of 183 ml in 35 days of bed rest[15] (Figure 2). This change is apparently the result of decreased RBC production. Increased tissue oxygen supply relative to need during the inactivity period may be the prime cause, resulting in decreased production and/or activation of erythropoietin, the hormone which has been shown to be capable of regulating red cell development. Upon return to activity in a normal gravity field there appears to be a slight hemolysis of red cells presumably due to direct trauma to the red cells from activity. This further exaggerates the RCM loss and slows return to normal.

Inactivity leads to a gradual decrease in stroke volume and therefore a rise in resting pulse rate. Since cardiac output (CO) is the product of stroke volume (SV) x heart rate (HR) and since maximum HR response to work is relatively fixed for a given individual, this usually results in a decrease in maximum CO capability.

Inactivity of skeletal muscle leads to loss of muscle mass and muscle strength[7]. Independent of both these factors may also be loss of endurance for muscle work. These changes may affect not only muscles of locomotion but also muscles of ventilation and result in a decreased ability to move air maximally or a reduction in maximal ventilatory capability. Decreased muscle tone and contractile force may also reduce the component of venous return related to muscular effects.

The summary of all of these decrements results in a significant decrease in work capability. Figure 3 demonstrates the results of exercise stress testing in our subjects where there is a significant decrement in work performance as seen by the reduction in time of exercise on the treadmill to reach a heart rate of 180 or to reach maximum heart rate in the immediate post bed rest period. There is also a significant decrease in oxygen consumption expressed as cc's per kilogram of total body weight or cc's per kilogram of lean body mass per minute. At three weeks post bed rest there remains a significant decrease in work tolerance as compared to the pre bed rest period. Efforts to prevent this decrement have not been completely successful although studies of exercise during the bed rest period are encouraging.

Many complex physiologic events are responsible for the maintenance of cardiovascular integrity in the upright position in a gravity field. A vertical tilt causes a rapid caudal shift of from 500 to 750 ml of blood in the venous system resulting in a decrease in SV (-45%), CO (-27%) and cerebral blood flow (-21%)[2,16,24]. There are, in addition, other alterations which are functionally important such as widespread reflex vaso- and veno-constriction based on pressoreceptor activation, a lessened cardiac reserve probably due to cardioinhibitory reflexes[25], and hyperventilation[3]. All of these influence circulatory performance and the susceptibility to syncope.

The critical cardiovascular defect in postural stress intolerance is an inadequate central blood volume[25], but the postural stress intolerance that follows bed rest or weightlessness may involve other factors as well. The decrease in blood volume described previously as associated with bed rest or weightlessness would be expected to influence tolerance to postural change. That this is not the paramount factor has been shown by the continued orthostatic intolerance of the Gemini astronauts postflight for many hours after their blood volumes returned to preflight levels[5] and by failure of the correction of blood volume using 9-alphaflurohydrocortisone to obviate the orthostatic intolerance seen post bed rest[19]. On the other hand, exposure of subjects to lower body negative pressure during the final few days of bed rest has obviated the orthostatic intolerance.

Reflex vaso- and veno-constriction, mediated via the sympathetic nervous system with release of pressor substances such as norepinephrine at vascular nerve endings causing vascular smooth muscle contraction, plays a major role in maintenance of central venous volume, cardiac output, and flow dynamics in response to the upright posture[20]. It has therefore been postulated that post bed rest orthostatic intolerance may be based on a failure of adequate sympathetic responsiveness which would be reflected

by a decrease in norepinephrine secretion. Two studies in this regard have been contradictory in results[10,22], while a later study confirms the decrease in norepinephrine excretion during bed rest and points up the normal venous wall response to exogenous norepinephrine and the alteration of venous response to tyramine in the post bed rest period, suggesting depletion of endogenous norepinephrine[17].

Whether this be the mechanism or not, there does appear to be an enhanced venous pooling in the upright posture post bed rest as evidenced by the observed increased venous engorgement, dependent cyanosis and increased leg circumference on tilt in these subjects[14,7]. Decrease in tissue turgor as a result of the absence of hydrostatic forces normally promoting extravasation of fluid into tissue spaces in the upright posture may remove a significant, contributory mechanism to the prevention of venous pooling. Decreased skeletal muscle tone, strength and mass may have a similarly significant role.

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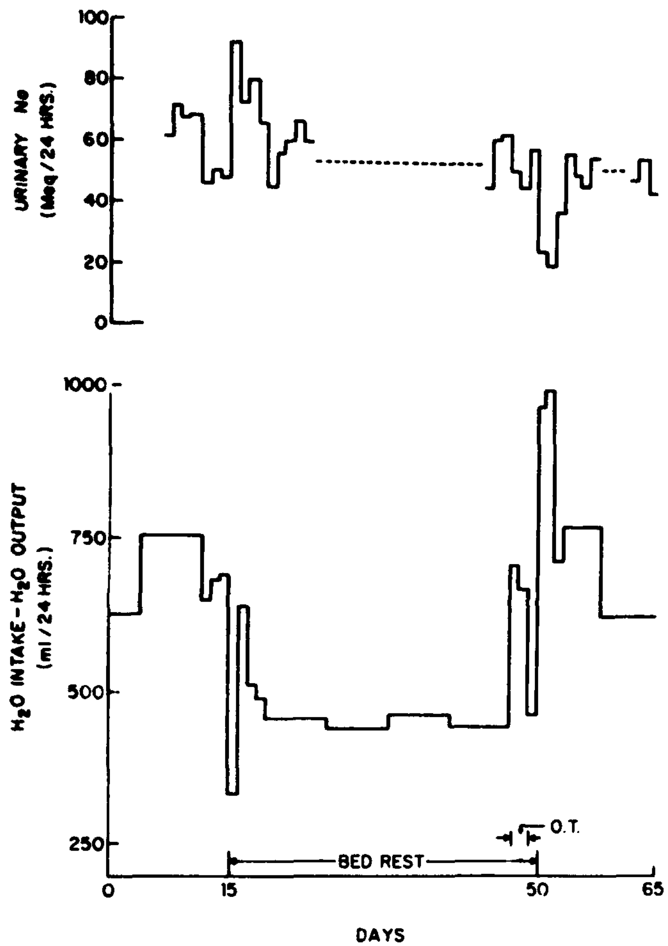

Figure 1. Water Balance and Sodium Excretion. Values of water balance correspond well with plasma volume changes seen during bed rest. Orthostatic tolerance testing (O.T.) produces the expected water retention, and upon assumption of activity at end of bed rest the water lost at onset of recumbency is recouped and balance returns to the pre bed rest value.

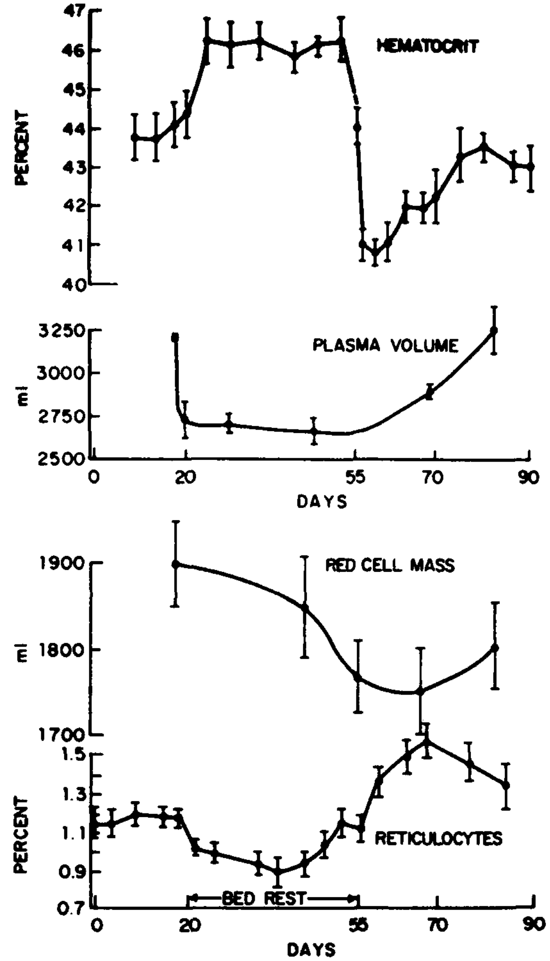

Figure 2. Hematologic Changes during 35 days bed rest showing correlation of plasma volume changes with red cell mass and hematocrit. Lower graph demonstrates the decreased reticulocyte count during bed rest with a rise in post bed rest period.

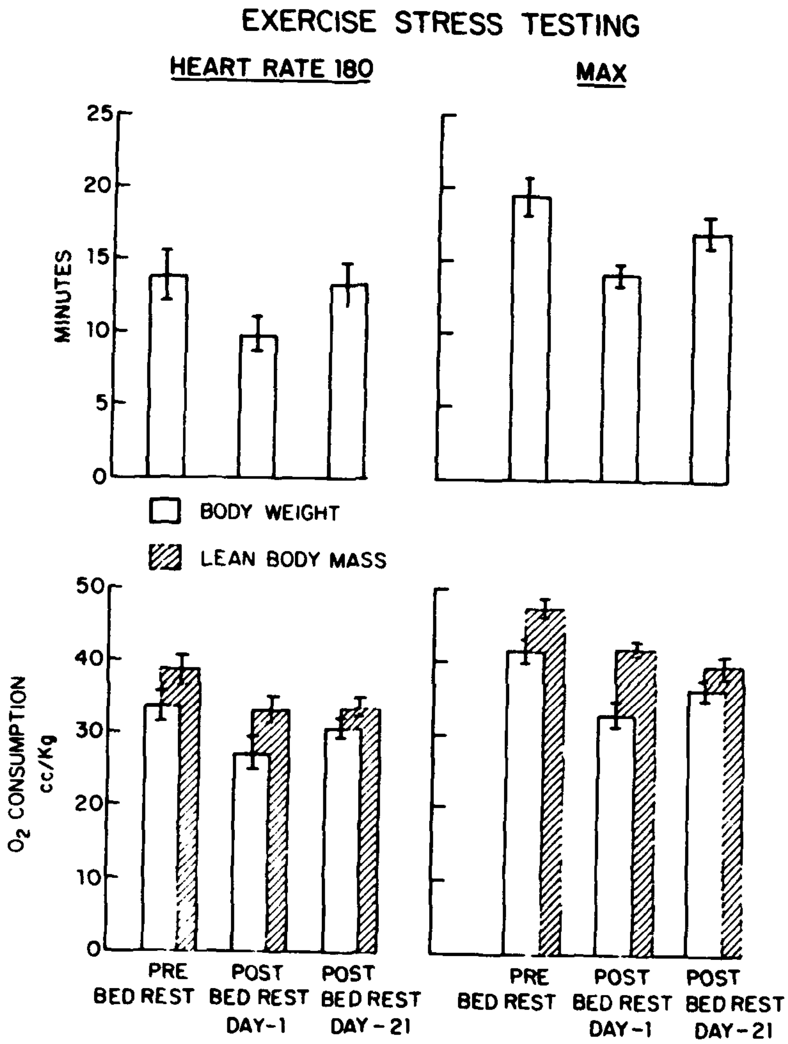

Figure 3. Exercise Tolerance Testing. Upper left panel shows time to reach heart rate 180; lower left panel demonstrates V_{02} at heart rate 180. V_{02} expressed in cc/kg total body weight and cc/kg lean body mass; upper right panel shows time to reach maximum heart rate; lower right panel shows V_{02} at maximum exercise. In each panel there is a significant decrease at 1 day post bed rest, and at 3 weeks recovery.

THE METABOLIC AND HEMATOLOGIC ASPECTS OF HYPODYNAMICS

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SUMMARY

The metabolic and hematologic consequences of prolonged bed rest have been correlated to those observed and postulated in weightlessness. Some are a result of a change in level of activity and others are secondary to a change in posture.

The caloric requirement and metabolic rate decreases. The nitrogen, sulfur, and potassium balances become negative. Their ratio indicates depletion of muscle mass. The calculated total muscle mass loss over a six week period is approximately 1.7 kilograms. However, the body weight remains constant at the expense of increased adipose tissue formation.

There is a progressive increase in urinary calcium excretion during bed rest which is independent of the calcium intake.

In addition to a decrease in plasma volume, there is a reduction in the red cell mass. Ferrokinetic studies, as well as other tests, suggest decreased red cell production during bed rest. During recovery a further decrease is noted. Several studies suggest hemolysis as an explanation for this observation . Cortisol production and its diurnal variation is not appreciably altered. During bed rest, the postural effect on aldosterone secretion is eliminated, resulting in a near constant production varying with the metabolic needs. Antidiuretic hormone and catecholamine production is also diminished during bed rest.

THE METABOLIC AND HEMATOLOGIC ASPECTS OF HYPODYNAMICS

EXPOSURE OF man to weightlessness as encountered in orbital flight has revealed alterations in cardiovascular dynamics, plasma volume, and red blood cell mass. These and other aberrations that occur during subgravity are poorly understood. Prolonged bed rest and water immersion studies correlate well with what has been observed in weightlessness. This would indicate that at least some of the alterations in the metabolic and hematologic homeostasis are secondary to a change in level of activity and/or posture. For this reason, the term hypodynamics is used instead of weightlessness. The applicability of ground-based experiments to actual space missions or weightlessness is questionable. This can only be answered by performing appropriate studies in space flight. What is known to occur under these conditions should not be considered pathologic in terms of disease but rather normal physiologic responses to an alteration in man's environment.

The discussion which follows will be a summary of the literature as well as the ground-based experiments performed within the United States Air Force School of Aerospace Medicine.

GENERAL METABOLISM

During immobilization, the caloric expenditure and resultant caloric requirement are diminished by 30%. The basal metabolic rate is reduced[2,10]. When maintained on an isocaloric diet, the body weight remains relatively constant at the expense of a reduction in muscle mass and a concurrent increase in adipose tissue formation (Figure 1)*. During bed rest, there is a decrease in muscle group circumference again suggesting a loss of muscle mass[10]. Dietrick, Whedon, and Shorr found a twenty one percent decline in the gastrocnemius-soleus muscle group strength after six weeks of bed rest. This decrement required four weeks to recover after immobilization. All of the subjects studied in our laboratory have demonstrated joint discomfort and difficulty with walking upon resumption of ambulation. This may be related to weakness of the supporting muscles.

NITROGEN BALANCE

A normal man is in apparent positive nitrogen balance when active. During the first week of bed rest, the positive balance becomes negative and will reach a peak about the tenth day of immobilization (Figure 2). Subsequently, there is a general decline to an equal balance during the remainder of bed rest. The balance becomes positive immediately after resuming ambulation. The total nitrogen loss during four to six weeks of bed rest amounts to approximately 54 gm.-1.7 kilograms of muscle mass[10]. This loss is greater in paralytic patients and probably is related to muscle tone[36]. Dietrick and his coinvestigators have demonstrated that urinary sulfur and potassium parallels the nitrogen loss[10] (Figure 3). The sulfur to nitrogen ratio in muscle normally is 1-14. In their subjects, the loss was 1-15.8. This suggests muscle catabolism. The renal excretion of potassium is independent of sodium and parallels the nitrogen excretion.

Chamber studies in our laboratory have indicated that hypoxia reduces the negative nitrogen balance[15]. There has been some work showing that an oscillating bed is beneficial in unparalyzed patients subjected to strict bed rest[35]. Isometric exercises have been of little benefit. However, isotonic exercises are beneficial if the subject is actually conditioned while remaining recumbent.

*All S.E.(Standard Errors) given in the figures are appropriate when comparing between two group means at a given period or for placing confidence limits on a group mean at a given time. They are not appropriate when comparing two period means for a given group.

CALCIUM METABOLISM

Prolonged recumbency and water immersion result in an increased calcium excretion in the urine and feces. A negative calcium balance occurs within two weeks of bed rest and reaches a peak by the sixth week (Figure 4). There is a lag in the recovery period before the balance becomes positive. The serum calcium remains relatively unchanged.

Dietrick and others have found that the total calcium loss approximates 0.5% of the total body stores during six weeks of immobilization[10]. If this loss were distributed evenly throughout the skeleton, there would be little concern over its structural effect. However, trabecular bone has a greater surface area per unit weight. Therefore, this suggests that the weight bearing bones would suffer the greater loss.

Radiodensitometry studies have confirmed the development of osteoporosis during the Gemini flights and immobilization[16,32]. The osteoporosis occurs first in the site of active bone formation[37], and can be detected within the first week of bed rest. Calcium kinetic studies have demonstrated an increase in bone resorption in the face of normal or even increased formation[12]. Little is known about the control of bone resorption. Loss of muscle activity which results in decreased stress of muscle traction, as well as lack of gravity, certainly plays a role[23]. The use of a rocking bed in normal volunteers subjected to prolonged recumbency has been of benefit; not so in paralyzed patients[22,35,38]. Isometric exercises have done little to prevent this complication[3]. There is evidence that isotonic exercises resulting in stress being applied to the musculoskeletal system parallel to the weight bearing bones would be of benefit. Little is known about parathyroid hormone, thyrocalcitonin, and the responsiveness of the bone, kidney and gastro-intestinal tract to vitamin D during prolonged immobilization. Recent exciting discoveries in the physiology of thyrocalcitonin might have direct application to the prevention of osteoporosis during immobilization and weightlessness.

The possibility of forming urinary calculi deserves consideration[16,21]. During bed rest, there is noted an increase in the urinary calcium, phosphorus, and pH with no attendant increase in the urinary citrate level[10] (Figure 5). In addition, there is a tendency for urinary stasis. These favor stone formation. Urinary calculi have not been a problem in actual space missions or immobilization studies involving healthy subjects. The incidence of recumbency stones in paraplegic patients is common. Infection and urinary stasis are the important contributory factors in this group.

The calcium intake has little effect on the urinary calcium excretion[39] (Figure 6). In addition, restriction of the calcium intake would appear harmful[22,39] (Figure 7). As a result, a 1 gm. calcium diet is used in this laboratory. With our present state of knowledge, the best means of avoiding urinary calculus in space would be appropriate investigative procedures in astronaut candidates to rule out potential stone formers.

ENDOCRINE FUNCTION

Endocrine function during immobilization has been poorly studied. It is known that the secretion of aldosterone does vary with position and is not diurnal in the same fashion as the other adrenal cortical hormones[20,30]. During bed rest, the postural effect is eliminated and there appears to be a constant production varying with the metabolic needs. Aldosterone and antidiuretic hormone secretion are reduced during bed rest and water immersion. The recent Gemini flights, have demonstrated that antidiuretic hormone and aldosterone appear to respond normally to the stress of re-entry[9].

Norepinephrine secretion is postural dependent[28,33]. It is diminished during water immersion[17]. There is evidence that it does not increase to meet the stress of passive tilting to an upright position after prolonged recumbency and water immersion[11]. Schmidt and his coworkers have recently presented evidence suggesting that the norepinephrine stores are depleted during water immersion[24]. This change is probably a significant contributory factor to the orthostatic intolerance that occurs as a result of immobilization.

The diurnal variation or circadian rhythm of cortisol production is unchanged during short-term immobilization and water immersion[14,34]. Further study is needed during prolonged weightlessness.

Thyroid hormone secretion remains unchanged during prolonged immobilization. As mentioned earlier, little is known about parathyroid hormone and thyrocalcitonin function during immobilization.

HEMATOLOGIC ASPECTS OF HYPODYNAMICS

The recent Gemini missions have demonstrated loss of red blood cell mass and shortening of the predicted red blood cell chromium^{51} survival[1]. Broun, in 1923, gave evidence that inactivity resulted in decreased erythropoiesis[4,5]. Subsequently, several prolonged bed rest experiments have shown a decrease in the red blood cell mass ranging from 54 to 215 ml.[10,18,29,31]. The red cell mass values were obtained indirectly from the measurements of the plasma volume in all of these studies. These data can be criticized because of the uncertainty of the relationship between body and venous hematocrits when the steady state is perturbed. The majority of these reports do not mention the quantity of blood that was removed from each subject. An experiment was conducted in the USAF School of Aerospace Medicine by Morse[19] wherein 13 healthy male Air Force volunteers were subjected to 34 days of continuous absolute bed rest. In addition, eight comparable ambulatory volunteer subjects were used to control such variables as age, blood loss, and stability of the red blood cell mass and plasma volumes. Cr^{51} labeled autologous erythrocytes were employed for the red cell mass determinations and survival. Ferrokinetic studies were performed using Fe^{59}. Erythropoietin assays were performed on 24 and 72 urinary outputs.

There was an average loss of 183 ml. of red cell mass at the end of thirty five days of bed rest (Figure 8). Regardless of the method of presentation, the red cell mass expressed as milliliters of red cells or milliliters per kilogram of body weight, both demonstrated a significant reduction upon completion of bed rest (Figure 9). Three weeks later, the red cell mass remained significantly below the pre-bed rest determinations.

Plasma volumes were estimated indirectly from the red cell mass and corrected microhematocrit. During bed rest, there was an average reduction of 200 ml. In contrast to the red cell mass determinations, the plasma volume returned to values well above those obtained prior to bed rest during the recovery phase (Figure 10).

Serial hematocrit values increased from 44 to 47% during the first two days of bed rest (Figure 11). Thereafter a near steady state was achieved. Immediately after immobilization, there was a rapid decrease from 47 to 41%. This was followed by slow gradual increase which never returned to the pre-bed rest values within 35 days of recovery.

There was a 20% reduction in the reticulocyte response during bed rest. This was followed by a pronounced reticulocytosis during the immediate recovery period (Figure 12).

There was no change in the red blood cell survival during bed rest. However, during reambulation the survival was shortened (Table I). Body surface counting during these studies failed to reveal any significant splenic red cell sequestration.

Ferrokinetic studies demonstrated decreased red cell incorporation of Fe^{59} during bed rest with a rise during the post bed rest period (Figure 13).

Erythropoietin assays revealed changes that are not significant statistically. However, there was a slight decrease in production during bed rest and an increase following reambulation (Figure 14).

The reduction in the red cell mass during bed rest could be explained with one or more of the following mechanisms: (1) increased destruction, (2) blood loss, (3) sequestration, and/or (4) decreased production. Hemolysis was unlikely since the red blood cell survival was normal and the reduction in the reticulocyte response would be opposite that expected if hemolysis did occur. Blood loss was

unlikely since all the stools were negative for occult blood and the controls did not demonstrate comparable changes in spite of having the same amount of blood withdrawn for studies. Sequestration of the red cells was unlikely because the radioactive scans showed no major organ sequestration and there was complete mixing of the Cr^{51} labeled red blood cells within 12 minutes after injecting the isotope. When sequestration does occur, incomplete mixing is still evident thirty minutes after injecting the isotope.

The reduced uptake of Fe^{59} by the red blood cells, and decreased reticulocyte response, would suggest a decrease in red cell production.

The regulation of erythropoiesis has been extensively investigated in the past two decades. There is evidence that a renal enzyme, similar to renin, activates a plasma globulin to generate erythropoietin[7]. Erythropoietin is capable of differentiating the stem cell into an identifiable nucleated erythroid cell[27]. The primary stimulus for the secretion of erythropoietin is dependent upon the oxygen supply and demand of the tissues. Hypertransfusion of red cells or hyperoxia result in an increased oxygen supply to the tissues which in turn shuts down erythropoietin formation and as a result decreases the rate of erythropoiesis. During bed rest, the decreased tissue demand for oxygen relative to the oxygen supply may be sufficient to alter the secretion of erythropoietin. This experiment would tend to confirm this hypothesis. Chamber studies involving immobilization and hypoxia failed to reveal reduced erythropoiesis[15].

After completion of bed rest, there was a rather marked fall in the hematocrit and a shortened red cell survival. The reticulocyte response was compatible with hemolysis or increased rate of erythropoiesis. The increased incorporation of Fe^{59} within the red cells confirms an increased rate of erythropoiesis. The lack of increase of the red cell mass in the face of an increased red cell production, suggests a compensated hemolytic syndrome in which the rate of production balances the rate of hemolysis. These findings are similar to those observed in some patients with mechanical traumatic hemolysis secondary to intracardiac prosthetic devices[25]. This has also been observed by Broun when studying dogs after prolonged periods of inactivity[4,5]. Perhaps the hemolysis results from mechanical trauma to the red cells in the feet as the subject walked[8]. Although definitive proof is lacking, it is tempting to speculate that the increased and perhaps turbulent blood flow through stiff joints, tender soles, and laxed muscles is the mechanical trauma necessary for hemolysis.

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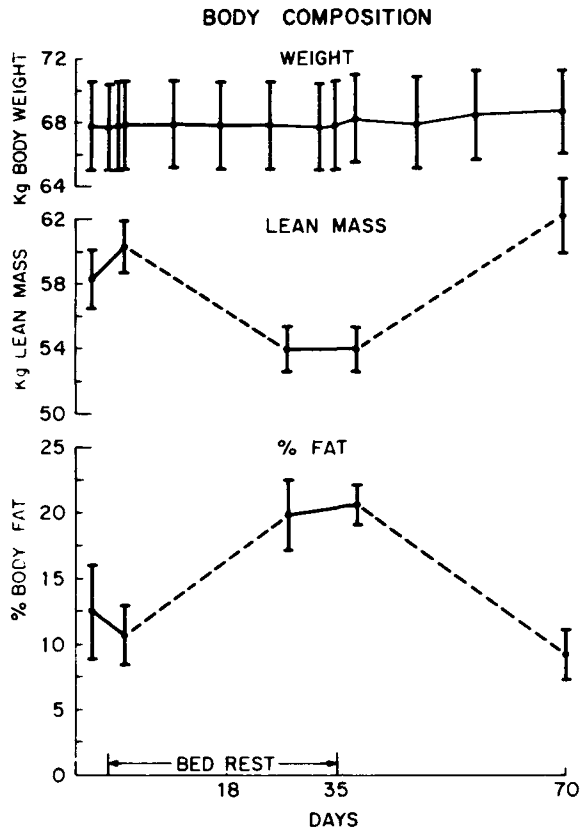


Fig.1 Body composition calculated from total body water measured by the tritium dilution technic. (mean ± 1 S.E. (see footnote page C 2-1))

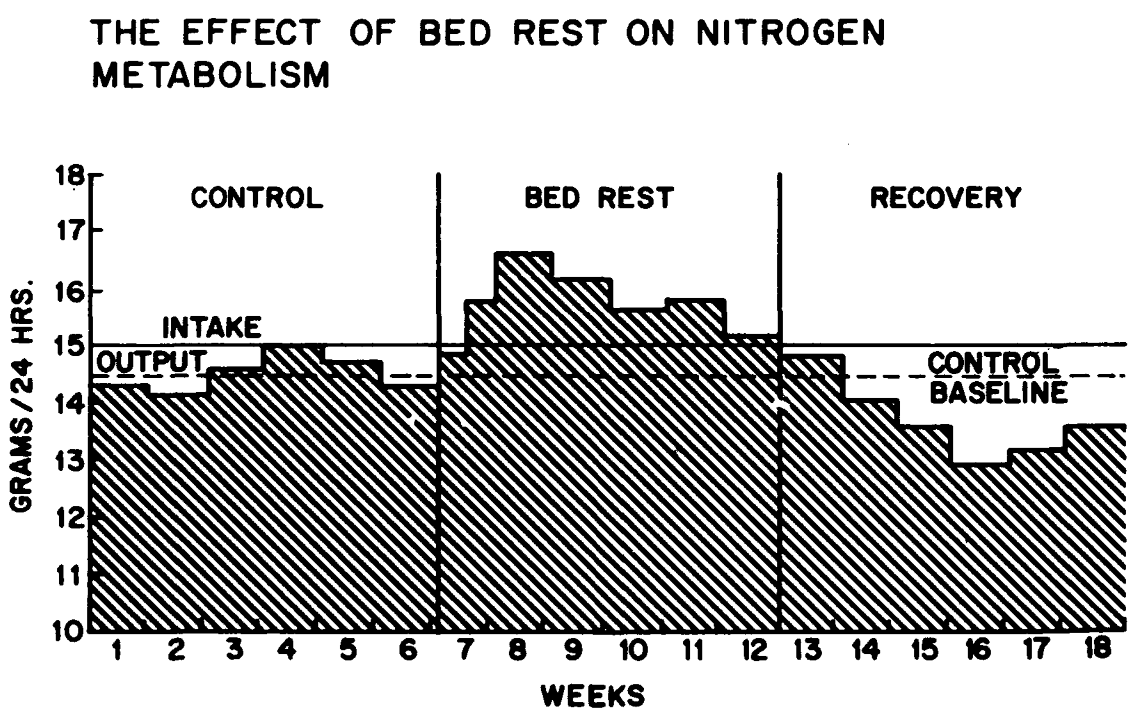


Fig.2 Nitrogen balance

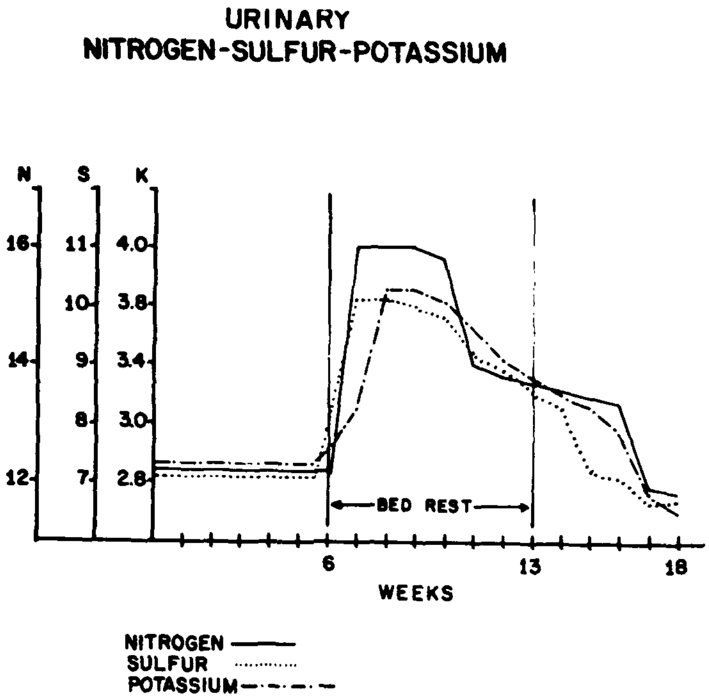


Fig.3 Urinary excretion of nitrogen, sulfur, and potassium during bed rest. (After Dietrick Amer. J. Med., 4:3, 1948)

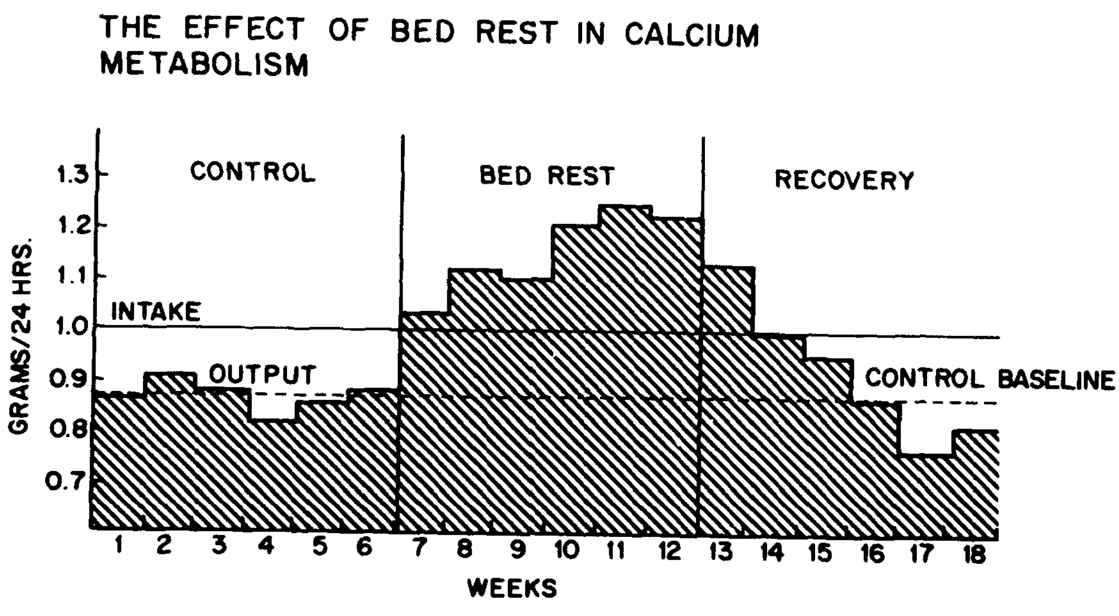
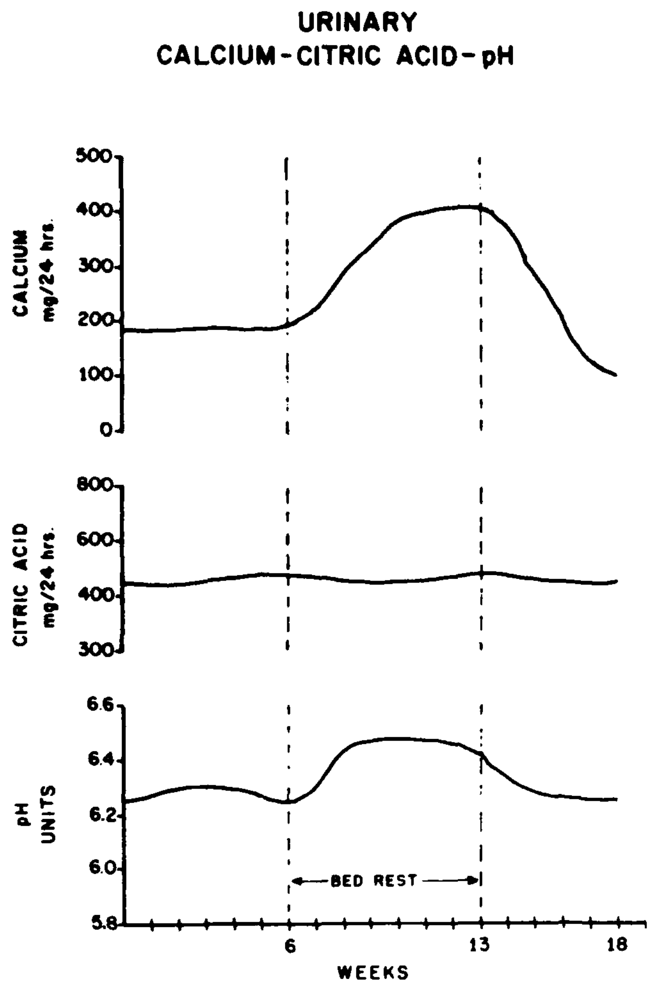


Fig.4 Calcium balance



(After Deitrick Am. J Med. 4:3 1948)

Fig.5 Urinaıy calcium, citric acid and pH during bed rest

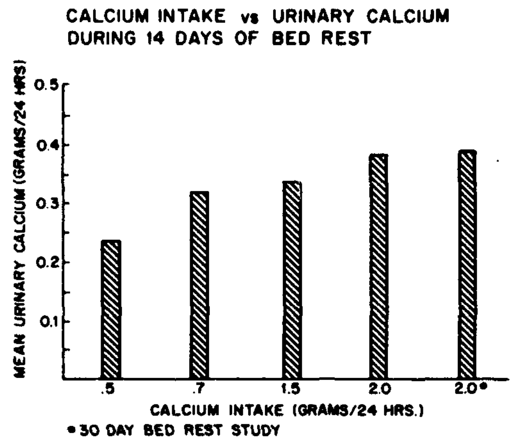


Fig.6 The effect of calcium intake on the urinary calcium during bed rest. (After Mack, P. B., NASA-SP-64)

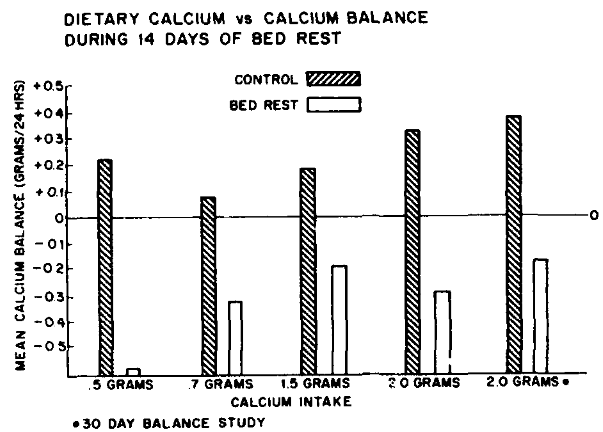


Fig.7 The effect of calcium intake on the calcium balance during bed rest. (After Mack, P. B., NASA-SP-64)

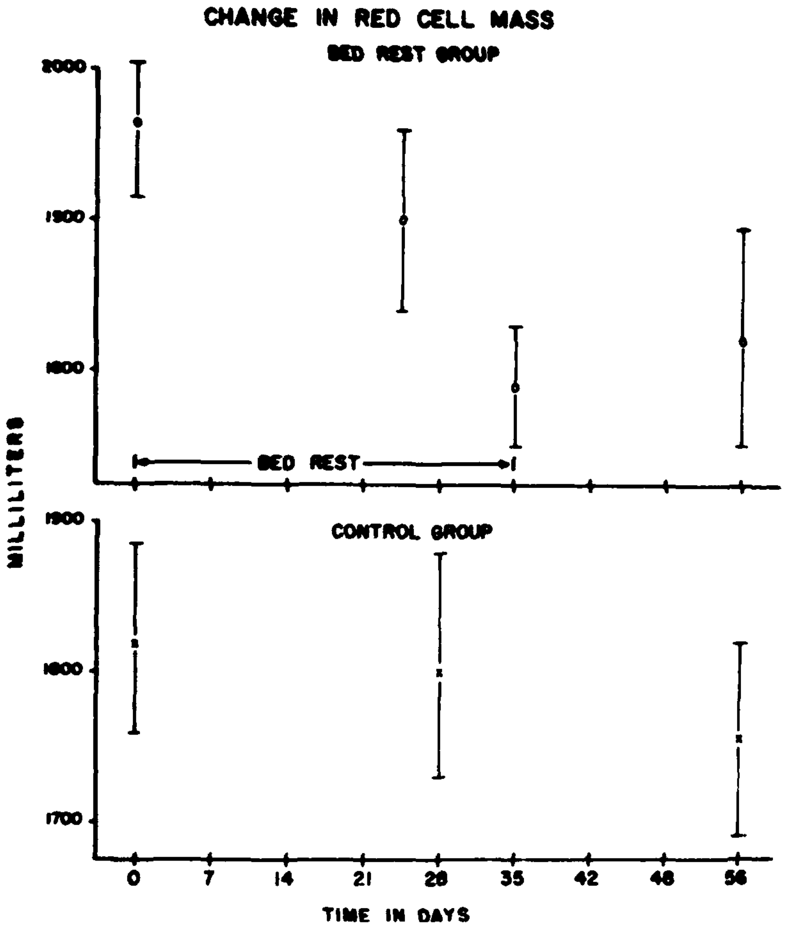


Fig.8 Change in the red cell mass during 35 days of bed rest in milliliters (mean ± 1 S.E.)

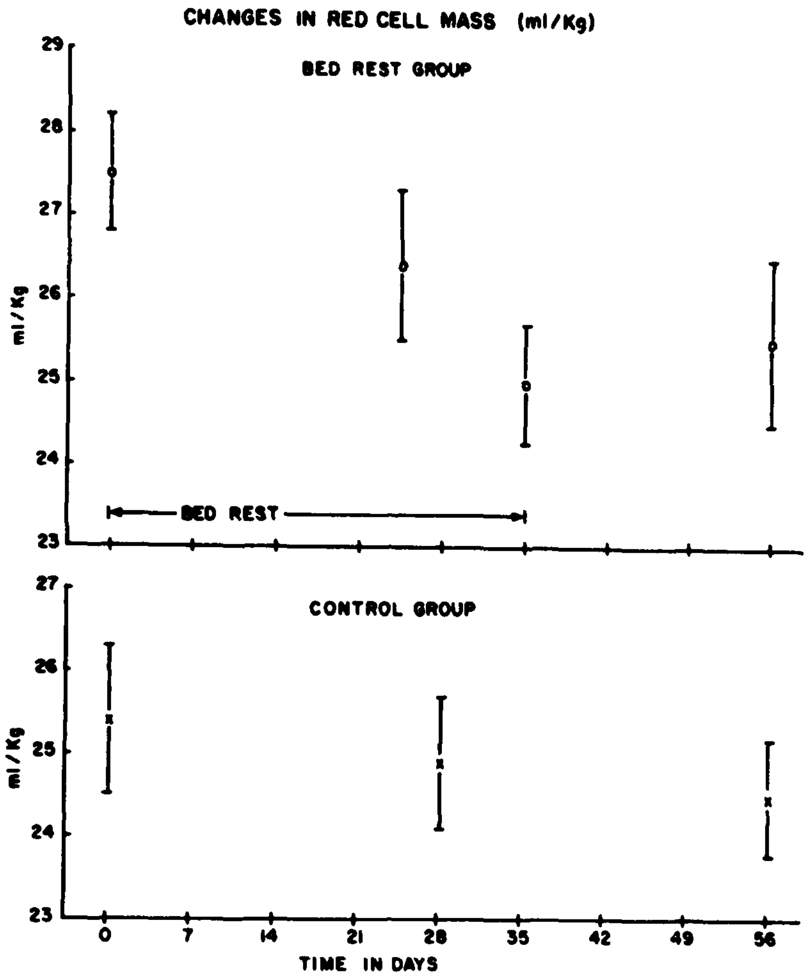


Fig.9 Change in the red cell mass during 35 days of bed rest as a function of body weight (ml./Kg.) (mean ± 1 S.E.)

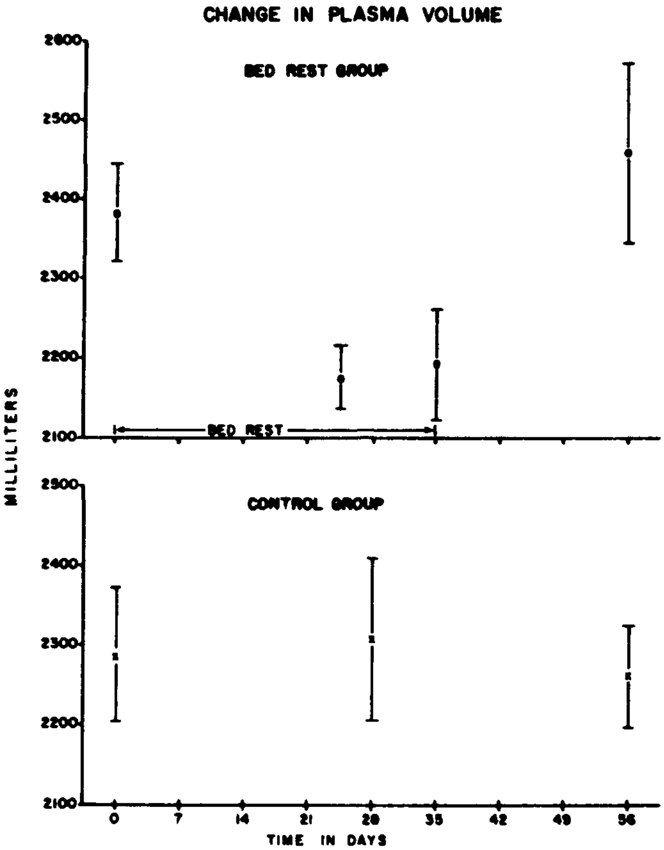


Fig.10 Plasma volume (mean ± 1 S.E.)

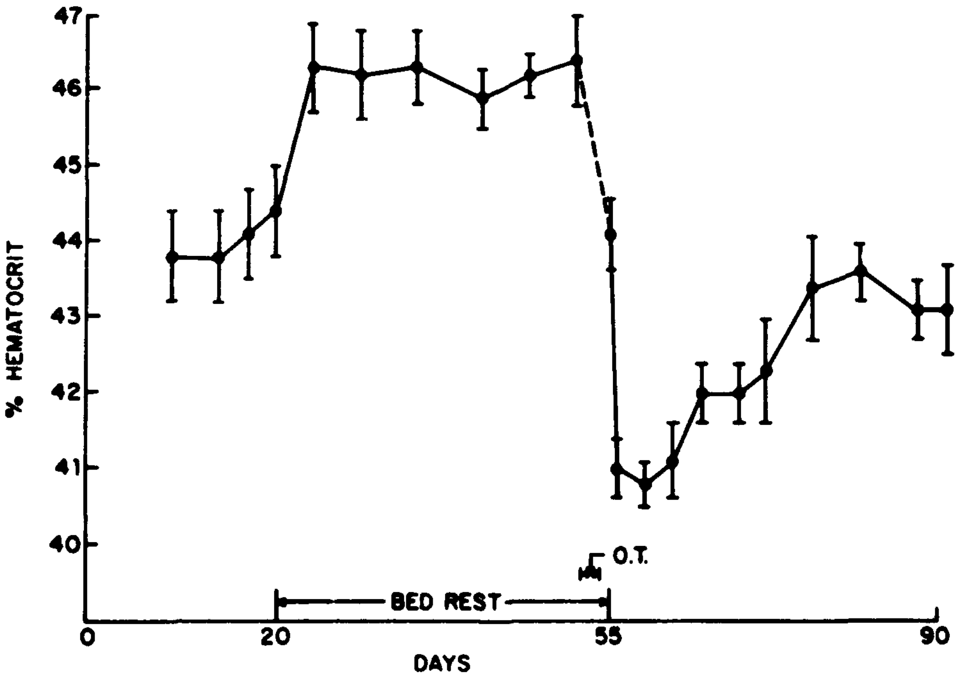


Fig.11 Serial changes in the microhematocrit (mean ± 1 S.E.)

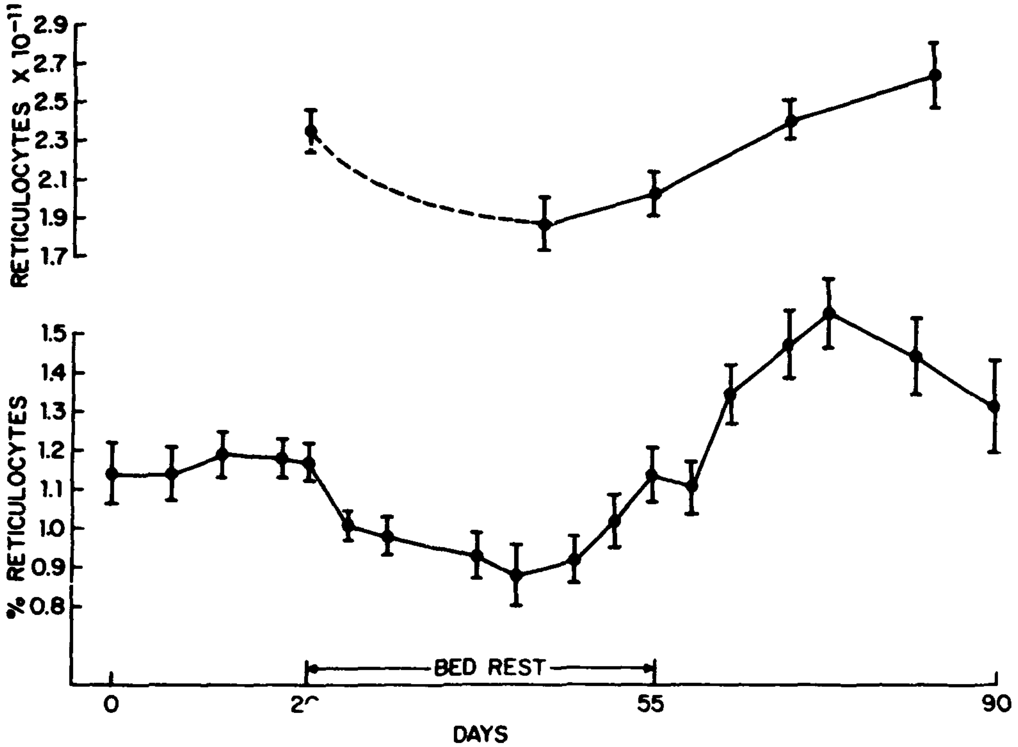


Fig. 12 Serial changes in the percentage and absolute number of reticulocytes estimated from peripheral blood smears (mean ± 1 S.E.)

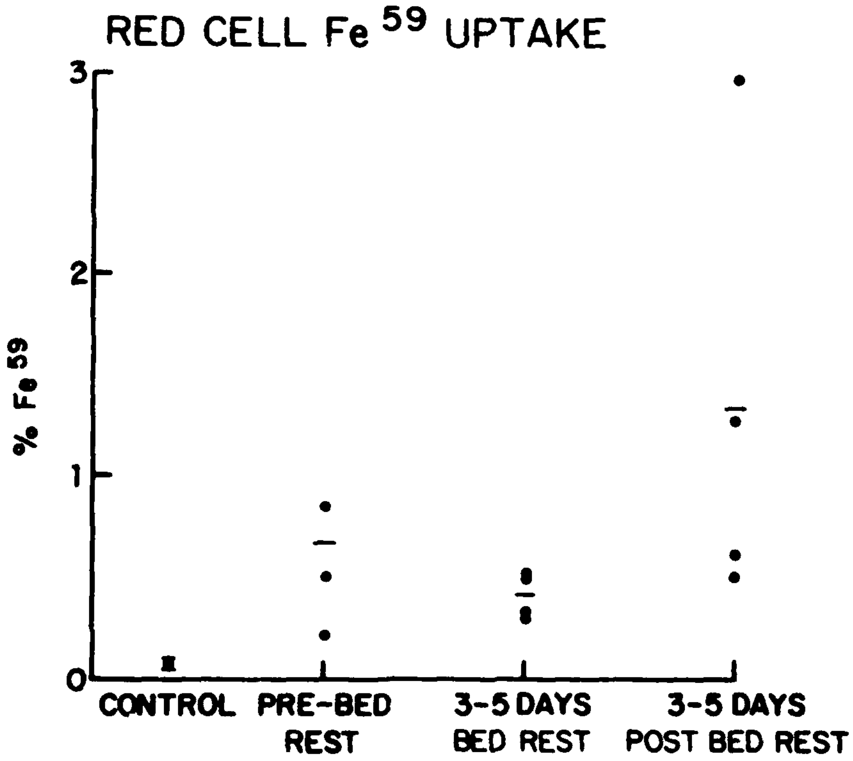


Fig. 13 Red Cell Fe^{59} uptake for 4 subjects studied

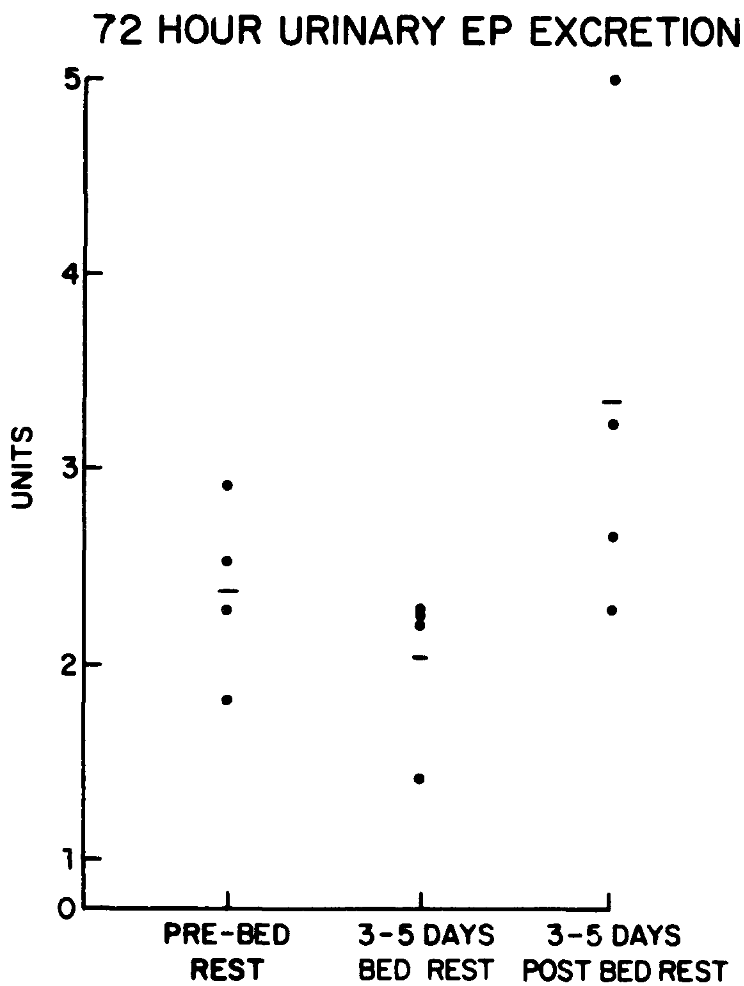


Fig.14 Urinary erythropoietin for 4 subjects studied

TABLE I

Cr^{51} red cell half survival values

Cr^{51} RED CELL	T -1/2 (days)
CONTROL PERIOD	25.4 ± 1.1
BED REST I	26.7 ± 0.9
BED REST II	28.7 ± 0.8
AMBULATION	20.7 ± 0.7

Bed rest I and II corresponds to the first and 24th day of bed rest, respectively (mean ± 1 S.E.)

C.3

OBSERVATIONS ON THE GAS TENSIONS OF MIXED VENOUS BLOOD IN MAN

by

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OBSERVATIONS ON THE GAS TENSIONS OF MIXED VENOUS BLOOD IN MAN.

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During rebreathing, the gas pressures in the respirate change towards those in mixed venous blood. For the first few breaths, the passive equilibration processes are masked by mixing artefacts, and later they are disturbed by the effects of recirculation. However, in normal subjects rebreathing from a small bag (< 5 litres) at 1 cycle/sec, the undistorted processes can be recognized during an interval roughly lasting from the 4th-10th seconds ("the plateau period"). The volume and composition of the rebreathed gas can be adjusted so that no gas exchange occurs in this time; then it is assumed that the gas pressures of the respirate equal those in mixed venous blood (Burwell and Robinson 1924 a and b; Cerretelli et al 1966; Denison et al 1966). Records at this time show horizontal plateaux. A method of accurately and rapidly varying the amount and content of rebreathed gas has been described (Denison 1967).

Over the past four years, some five thousand rebreathings have been recorded by respiratory mass spectrometry, in resting and exercising subjects exposed to a wide variety of stresses (Denison 1968). These show that satisfactory O_2 and CO_2 plateaux can be obtained in all tolerable degrees of hypoxia, hypercapnia, hyperventilation, tube-breathing and resisted respiration - providing subjects expire to residual volume before rebreathing, and that the two plateaux are obtained simultaneously.

Plateaux show measurable slopes when they deviate more than 1 mmHg from the horizontal value. If sloping plateaux, recorded during the same steady state, are extrapolated, they lie within 1.5 mmHg of the horizontal value at the 20th sec. and intersect with each other within the same limits. The rebreathing procedure causes small (2 mmHg) falls in venous O_2 and CO_2 tensions, that disappear within 2 minutes.

Cardiac outputs can be estimated if measures of venous gas tensions are combined with corresponding arterial values (predicted from end-tidal gas pressures) and standard dissociation curve data. Estimates based on CO_2 exchange are consistently some 10 % higher than those derived from O_2 transfer. The reason for this difference is not yet clear, but both sets of estimates agree well with published measurements made by other techniques.

It seems that rebreathing techniques can be employed to measure mixed venous gas tensions with a resolution of 1 mmHg and a probable accuracy of 2 mmHg. The method can be applied to steady and unsteady states, does <u>not</u> need an automatic gas dispenser or continuous gas analysers and may be repeated every 2 minutes without disturbance of steady state. Also in steady states, it can be used to measure cardiac output to within ± 10 %.

Theoretical analyses show that, in respiratory steady states, the mixed venous P_{CO_2} is determined almost entirely by alveolar ventilation while the corresponding oxygen tension is regulated by blood flow; one would, therefore, expect that threats to tissue oxygenation would be met by alterations in perfusion while disturbances in tissue CO_2 stability would be countered by adjustments of ventilation.

Figure 1 illustrates how these predictions are fulfilled in practice. It represents the average responses made by four normal subjects to mild, moderate and the maximal tolerable, degrees of various stresses, during exercise on a cycle ergometer. All of the measurements were made in steady-state exposures of 25–45 minutes' duration. The venous gas tensions (Fig 2) indicate the extent to which these homeostatic responses failed. In both figures, a shaded area encompasses the range of control values. Amongst the observations that can be drawn from the two diagrams are these:

1) Wide swings in environmental gas tensions caused small changes in the gas pressures of mixed venous blood. Rises in inspired CO_2 tension were largely buffered by raised ventilation. Falls of inspired oxygen pressure were principally met by an increase in blood flow.

2) Venous oxygen tension was controlled to the same degree as arterial P_{CO_2}.

3) During light exercise in air, hyperventilation caused a steep fall in $P\bar{v}_{CO_2}$ and a slight fall in $P\bar{v}_{O_2}$. It did not seem to alter cardiac output.

4) During light exercise, in hypoxia equal to an altitude of 10,000 ft, hyperventilation led to a sharp fall in $P\bar{v}_{CO_2}$ but a small rise in venous P_{O_2}. Cardiac output appeared unchanged.

5) Hypoxia produced a 1:1 drop in both tensions, with an 80–95 % homeostasis of the fall in inspired oxygen pressure.

6) CO_2 breathing caused a 2:1 rise in both tensions with a 50–75 % homeostasis of the rise in inspired CO_2 pressure. Part of the smaller increase in oxygen tension was due to a rise in blood flow. The physiological purpose of this is not clear.

7) Asphyxia caused a progressive rise in venous CO_2 pressure, but no change in Pv_{O_2}. This was true whether the asphyxia was produced by tube-breathing or by altering the inspirate. Some of the fall in inspired oxygen pressure was buffered by a CO_2 driven hyperpnoea.

8) Exercise led to roughly a 1:1 fall of Pv_{O_2} and rise in Pv_{CO_2}. The effects were most marked in the transition from rest to exertion.

9) Exercise in oxygen produced a similar change, but there was a 10 mmHg rise in Pv_{O_2} and an up to 9 mmHg increase in Pv_{CO_2} at all grades. There was no apparent change in cardiac output.

10) Inspiratory and expiratory resistances disturbed the control of ventilation, but had no important circulatory effects.

11) For predictive purposes, it seems reasonable to take 70 mmHg as the highest tolerable Pv_{CO_2} and 17 mmHg as the lowest acceptable Pv_{O_2}.

Conclusion.

Mixed venous gas tensions have not been measured frequently in the past. Modern instruments have made it easier to do so. This small series of observations, made over a wide range of conditions, suggests that a rebreathing technique can measure them and that they behave in the way expected if 'in vitro' dissociation curves were to apply 'in vivo'.

Experiments completed since the presentation of this paper have shown that:

a) the method can be applied to the study of exercise during total water immersion (Denison, Tonkins, Ernsting and Davies 1969).

b) a complex relationship exists between the CO_2 tensions of pulmonary artery blood and rebreathed gas, although their oxygen tensions are identical (Denison, Edwards, Jones and Pope 1969 a and b).

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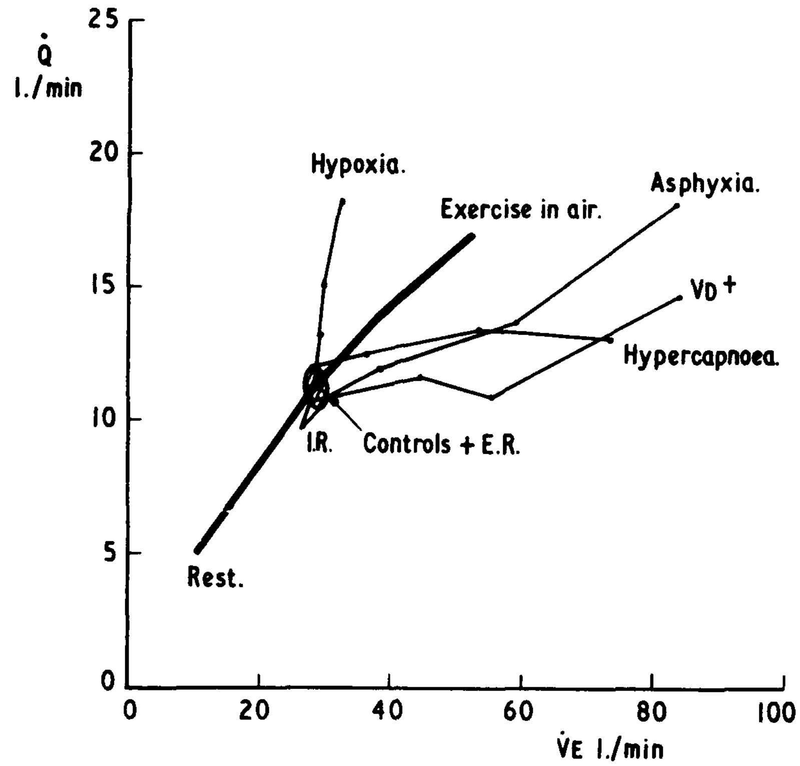

Fig.1 A $\dot{V}E/\dot{Q}$ plot of the responses to each stress

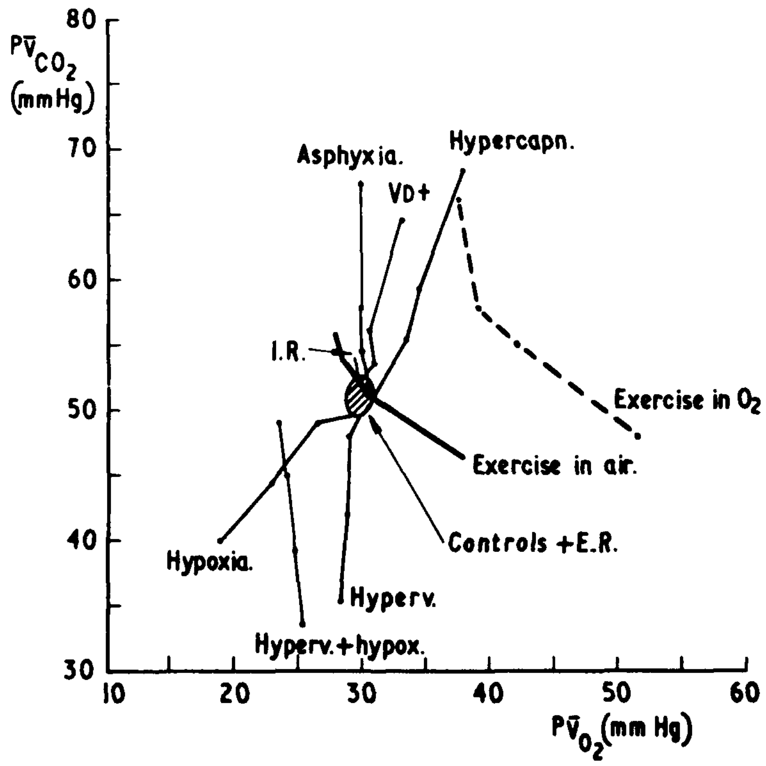

Fig.2 How venous gas tensions were influenced by several conditions

THE EFFECTS OF PROLONGED EXPOSURE TO HIGH OXYGEN TENSION

by

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SUMMARY

The expected use of 100% oxygen at low pressure as the respiratory gas for astronauts makes it desirable to determine the effects of long term breathing of oxygen. Although this use is not symptom-free, experiments with animals and human subjects for periods up to 30 days have indicated a clear difference between the effects under these conditions and those at one atmosphere (760 mm Hg), mainly the absence of fatal pulmonary edema at low pressure. Our efforts have been directed toward the effects as manifested in rats during up to 47 days of exposure but principally at 30 days. These experiments are carried out at a pressure that is high but is just short of that capable of producing terminal edema -- 2/3 atmosphere. Under these conditions rats developed changes in the pulmonary vasculature that appeared to be hypertrophic and in some cases hyperplastic that suggested a greater turnover of tissue in the vessels. Further investigation showed that the rats developed pulmonary hypertension and systemic hypotension. In view of the vascular changes, these effects are attributed to an increased vascular resistance and a decreased cardiac output from the right heart. The long term significance of these effects have not been studied but it is suggested that they would be ameliorated by return to air breathing.

THE EFFECTS OF PROLONGED EXPOSURE TO HIGH OXYGEN TENSION

George H. Kydd, Ph.D.

From the time of its discovery, oxygen has stimulated the interest of biologists and others who wondered if its effects on animals and men resembled in any way the increased rate of combustion that occurred when a candle is thrust into it. Indeed, we may justifiably wonder about this question today as I shall point out below.

But aside from this somewhat basic interest, oxygen breathing is also of practical importance today and there exists a need to know something of its effects after prolonged breathing in high concentrations. It appears that in situations in which men are separated from the terrestrial environment at the earth's surface such as encapsulation, the question arises as to how closely the terrestrial P_{O_2} must be simulated. For example, in diving where the ambient pressure can increase the P_{O_2} of air to dangerous levels, one would like to know how much variation from normal P_{O_2} can be tolerated. Uniquely in medicine the need to supply a higher than normal P_{O_2} arises and with it a need for the time limitation the patient can breathe the higher concentration without suffering ill effects.

A third situation exists in the operation of a space capsule, where because of convenience or necessity, one may be required to breathe 100% oxygen at low pressure for prolonged periods. Examples of this are Mercury and Gemini projects in which astronauts breathed 100% O_2 at 5 PSIA.

As a result of interest generated by manned space flight, there have been a number of experiments carried out on animals and men in low pressure, high concentration oxygen. The results of these experiments indicate a tolerance of oxygen under these conditions that is in contrast with known oxygen toxicity and it would be well to point out the difference between tolerance and lethal exposure.

Most laboratory animals die when exposed to 100% oxygen at sea level (P_{O_2} 760 mm Hg) in 3-4 days of massive pulmonary edema (1,2,3,4,5,6). Young rats develop a resistance and survive (7) and monkeys seem to be more resistant, requiring the longest exposure of all the other animals (5, 6). Men also appear to be more resistant. In experiments involving 12 human subjects Doleval found that the time range to which the subjects would voluntarily expose themselves was from 74 to 110 hours. The subjects were very sick after this exposure but this is considerably longer than the survival time for small animals (8). In 1938 Armstrong (9) found that a reduction in pressure of 100% oxygen, reducing the P_{O_2}, would contribute to the survival of rabbits and Comroe in 1947 found that the chest pain associated with breathing 100% oxygen was absent when pressure was reduced to 1/2 atmosphere (10). Since that time and especially in the last few years, experiments (too numerous to mention here) in 100% oxygen at reduced pressure have been carried out. This includes those of Michel (11), Brooksby (12), Pepelko (13), those from the School of Aerospace Medicine at Brooks Air Force Base, Texas, Welch, et al (14, 15, 16, 17) and those of Caldwell (18) and our own (19, 20, 21). The conditions of these experiments are not uniform except that the percentage of oxygen was near 100% in all and the P_{O_2} was well below a level that would produce serious symptoms. If those with P_{O_2} below 417 mm Hg are considered together (12, 13, 14, 15, 16, 17) there are two observations of interest in a discussion of oxygen toxicity: 1. in these experiments that lasted up to 30 days, all subjects completed the experiments and were not incapacitated to the extent that they had to drop out prematurely, and 2. symptoms developed that have been referrable to oxygen toxicity, notably chest pain, and of course other symptoms that have not been associated with oxygen toxicity such as aural atelectasis. Our interest has centered around two factors: 1. the difference between oxygen at one atmosphere and at lower pressures and what it may tell us about oxygen toxicity, and 2. the nature and duration of the tolerance to low pressure oxygen.

In regard to the first point, we were interested in the fact that as the P_{O_2} is lowered from 650 mm Hg where typical O_2 toxicity is experienced in rats, a rather sharp difference in effects occurs in the 100 mm Hg down 550 mm Hg which is approximately the highest P_{O_2} of 100% oxygen that adult rats will survive and tolerate without exhibiting pulmonary oxygen toxicity. The pertinent question regarding these low P_{O_2}'s is this: Does long term breathing of oxygen at low pressure produce any effects and in investigating this question we have selected the highest P_{O_2} of this tolerable range 2/3 atmosphere with the idea that effects would more likely show up here.

Our early experiments in which rats were exposed to 95-100% oxygen at 550 mm Hg for 30 days indicated that microscopic examination of the lungs did indicate structural change (20). These occurred in the vascular system, possibly the bronchioles, and also changes which we believe to be emphysema in the epithelial tissue. Of particular interest were the changes in the vascular system. These appeared at times to be erosive and at other sites to be proliferative so that they gave an overall impression of increased turn-over of tissue in the vascular system.

The question arose as to whether or not the structural changes may give rise to detectable hemodynamic changes and this question was addressed in a series of experiments in which pulmonary and systemic hemodynamic changes were compared in exposed and non-exposed rats.

METHOD

The exposures were carried out in a facility that provided a 95-100% oxygen atmosphere shown in Figure 1. It consisted of a cylindrical animal chamber connected to an external circuit through which air was continuously pumped. The circuit contained a vessel of LiOH for absorbing CO_2, a heat exchanger, an oxygen regulator, temperature sensor (a thermistor), and sampling orifices for gas analysis. The reduction in pressure resulting from CO_2 absorption was sensed by the oxygen regulator which added oxygen to the system to maintain a preset pressure level. Approximately every second day, the chamber was opened to remove waste and add food requiring a total of 15-20 minutes for the purge. The chamber operated at 95-100% O_2, 28 ± 1°C and at a relative humidity from 30-70%, passively maintained and CO_2 was below 0.58%.

At the end of the exposure the rats were removed from the oxygen atmosphere, anesthetized with urethane (1 g/kilo) and provided with a tracheostomy and the abdominal aorta cannulated with a "T" tube near the bifurcation and connected by polyethylene tubing to a pressure transducer. The tracheostomy tube was provided with a closed breathing system that provided for removal of CO_2 by a special tube and a pressure transducer.

To measure pressure in the right heart, a double catheter connected to a transducer was inserted into the external jugular vein (see Figure 2). These were mounted one inside the other so that the smaller one could be pushed through the larger one. The smaller catheter was pre-formed to enter the pulmonary artery and it was thus curved almost 270°. The tip of the larger catheter was bent at about 45°. By observing the pressure pulse on an oscillograph and gently manipulating, the combination was maneuvered into the right ventricle where the small catheter was pushed through and maneuvered into the pulmonary artery. The large catheter was then with-drawn from the vessel. The position of the catheter was verified at autopsy after sacrifice with urethane.

An example of a recording is shown in Figure 3. A prominent characteristic of most of the recordings was caused by the effects of respiration which at times produced a variation almost equal to pulse pressure. Thus minimum systolic pressure that occurred during inspiration was just longer than diastolic pressure during expiration. In evaluating the pressures, a maximum and mean systolic pressure were computed along with a mean pressure. In this latter case, the diastolic pressure used in this computation was frequently negative when the catheter was in the ventricle.

RESULTS AND DISCUSSION

A summary of the pressures obtained is shown in Table I for the pulmonary circulation and Table II for the systemic. These data suggest a possible hypertension developing in the pul-monary circulation and a hypotension in the systemic. At this time we would attribute the for-mer to the previously cited structural changes in the lung vasculature as indicated by the in-creased systolic pressure produced there. The nature of the mechanism producing the change remains somewhat obscure, however, the effects of oxygen on the endothelium of the vessels of the lungs have been reported by Kistler, et al (22) who found that it was most vulnerable to oxygen.

TABLE I

Effect of Oxygen Exposure on Pressures
from the Right Heart when Breathing Air and Oxygen (mm Hg)

	Max. Systolic		Avg. Systolic		Mean Pressure		
Breathing Gas	Air	Oxygen	Air	Oxygen	Air	Oxygen	No. Rats
Exposed	43.3	42.4	37.6	35.4	15.5	16.1	17
Non-exposed	36.7	35.5	31.8	29.7	14.6	15.5	30

TABLE II

Effect of Oxygen Exposure on the Mean Aortic Pressure
when Breathing Air and Oxygen (mm Hg)

Breathing Gas	Air	Oxygen	No. Rats
Exposed	79.6	88.7	17
Non-exposed	90.7	99.6	30

In other studies at our laboratory, the question has been raised as to whether the animal that tolerates low pressure oxygen so well for prolonged periods can be distinguished from his unexposed equal. One approach to this question is to determine whether the response to oxygen itself can be altered by oxygen breathing. It had been reported earlier by Smith, et al (7) that

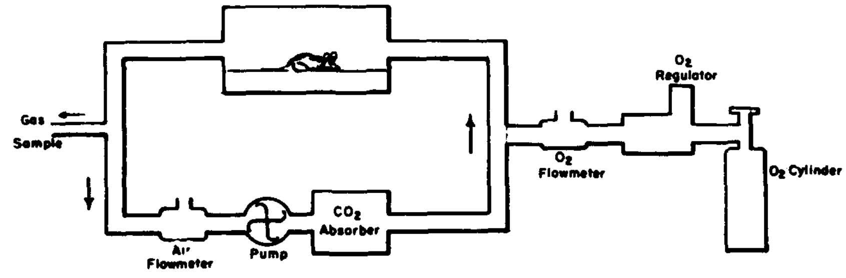

Figure 1. A diagram to illustrate the operation of the system in which the animals were exposed.

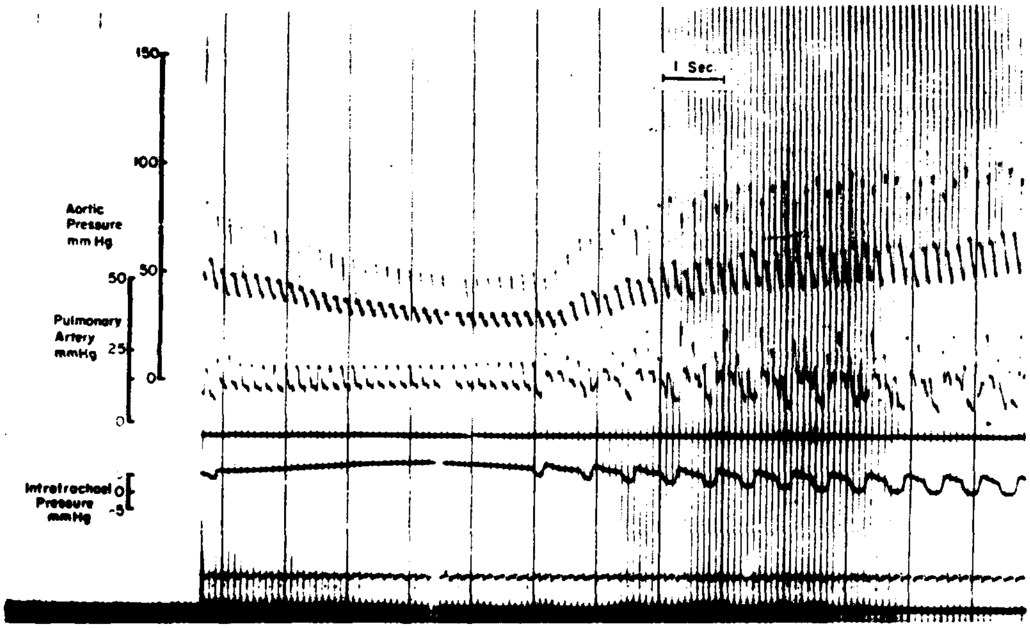

Figure 3. A reproduction of an oscillogram showing from the top, aortic pressure (A.P.), pulmonary arterial pressure and intratracheal pressure (I.P.), and ECG at the bottom. In the first part of the record, I.P. has been raised producing apnea. (From an exposed animal.)

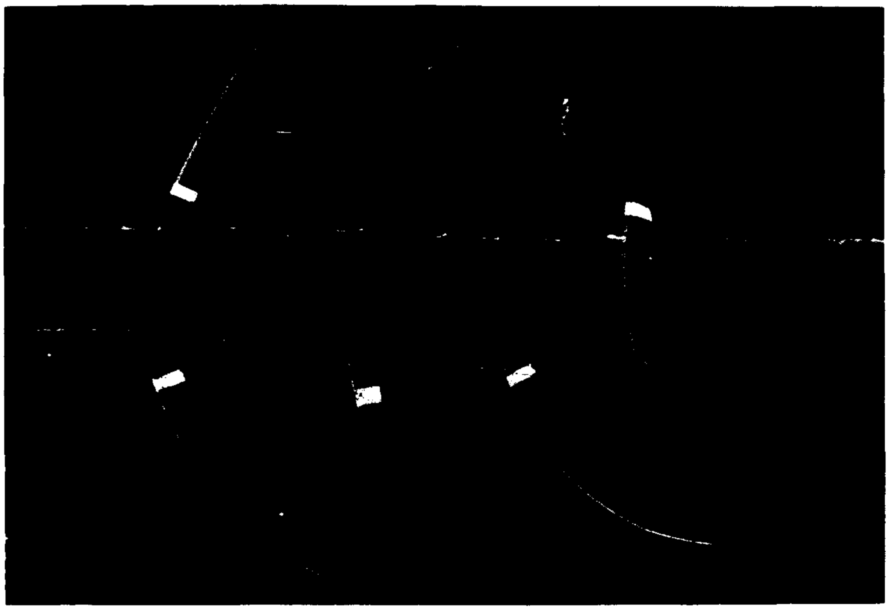

Figure 2. The catheter used for catheterization of the pulmonary artery.

rats exposed under compressed air could indeed be made tolerant to future exposure. In these experiments, rats that survived the initial exposure retained tolerance to future exposures In our experiments rats were exposed to 100% at 2/3 atmosphere for up to 45 days and as short as 15 days. At the end of the respective exposures the pressure in the chamber was increased to 1 atmosphere. Normal, adult, unexposed rats would have been expected to die in 3-4 days in extreme dyspnea of massive pulmonary edema and pleural effusion. Yet a large percentage of these pre-exposed rats lived and those that died did not die typically in dyspnea. Obviously, the pre-exposure at 2/3 atmosphere does produce an effect and contrary to what may be expected, it is beneficial, although there were no outwardly observable changes. Although survival of these rats was high, the fact remains that the second exposure did have its effect because all of the rats were sick, exhibiting delayed dyspnea (after the 4th day) and some had pleural effusion. Animals that survive the otherwise lethal exposure are of value not so much because they survive, but because they provide an oxygen poisoned specimen that is not rapidly terminal and the experimenter is allowed more time for study. This is the point of view and the approach we have taken and from this standpoint some observations are of interest: 1. the symptoms of the surviving animals are related to those of dying animals, namely, the pleural effusion and the respiratory difficulty. The process that produces fluid of edema and effusion has been arrested or the resorption process has been increased, or both of these have taken place yielding a situation that is relatively stable and compatible with life. It would appear, at this time, that the fluid formation may be related to the pulmonary hypertension that was demonstrated in these animals. This could be brought about by the endothelial changes already mentioned. One infrequently mentioned factor is the animal's capacity to absorb fluid from the lungs. Studies of other animals indicate that this is relatively large and consideration must be given this potential large capacity system in cases of pulmonary edema and pleural effusion.

It is our feeling that the 30-day exposure at 2/3 atmosphere is an agent for the production of fluid and that the duration of the exposure allows for an adaptation of fluid clearance mechanisms to greater capacity. This would involve the dilatation of lymph vessels in the lymph system as well as other mechanisms. Thus the sea level exposure would produce transudation in animals that were better able to clear it, avoiding a crisis; they are sick but they survive. The difficulty in proving this hypothesis is that we know so little about transudation in the lungs, short of terminal pulmonary edema.

It should be mentioned that pre-exposure at 1/2 atmosphere for 30 days did not protect rats indicating a difference between this and 2/3 atmosphere. The significance of structural and hemodynamic changes occurring at this latter pressure remain to be determined. They could be transient responses that are reversible on return to room air. Similar changes have been reported in dogs exposed for eight months at 5 PSIA (23).

We believe that these observations on the effects of oxygen support currently held hypotheses in the close relationship of oxygen toxicity and ionizing irradiations suggested by Gerschman, et al (24) and Gerschman (25). The initiating mechanism for these effects would be the formation of free radicals in tissue which is a function of ionizing radiation, P_{O_2} as well as metabolism. It is interesting that in another discussion of the effects of irradiation among others, Cassarett (26) mentions specifically the vascular bed as the prime site of action of the aberrant effects that proceed. The present observations on the effects of oxygen on the pulmonary vascular bed would seem to support this suggestion.

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FIRE PREVENTION AND PROTECTION IN OXYGEN ENRICHED ATMOSPHERES

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SUMMARY

The United States Air Force has expended considerable effort during the past year to enhance the fire safety aspects of ground based simulators which use oxygen enriched atmospheres in research, testing and hyperbaric therapy. This paper will discuss improvements which have been made in removing combustible materials, in removing ignition sources and in providing fire extinguishing systems. Improved noncombustible materials will be demonstrated. Slides and movies of the fire extinguishing systems will be shown.

THE IGNITION POINT OF MATERIALS in 100% oxygen at 1 atmosphere is much lower than the same material in air at 1 atmosphere. The burning rate of filter paper in air at 1 atmosphere is approximately 1 cm/sec as compared to approximately 4.3 cm/sec in 100% oxygen at 1 atmosphere.[1] A unique characteristic of fire in 100% oxygen is the extremely rapid surface burning characteristic or "nap" fire which instantaneously spreads over the surface of the combustible material and initiates multiple point sources.[2] (Figure 1) The Aerospace Medical Division conducts many experiments in which man is exposed to oxygen enriched atmospheres either as a human test subject or during the course of tending experimental animals or equipment. These potential hazards have caused the Aerospace Medical Division to modify significantly the fire prevention and extinguishment aspects of its simulators which use these atmospheres. This paper will describe some of the modifications which have been accomplished.

FIRE PREVENTION in oxygen enriched atmospheres should follow the basic axioms of fire prevention -- minimum combustible materials, minimum ignition sources and adherence to good practices in operation, maintenance and training. The first of these axioms is difficult to implement, however, as most nonmetallic materials will burn in 100% oxygen. Combustibles which should receive close scruitiny include, among others, uniforms, bedding, helmets and insulation on electrical wiring. Materials which were evaluated as replacement items included Nomex, Polybenzamidazole, asbestos, Beta Fiberglas, Teflon, Kapton and combinations of these. Each of the materials had advantages and disadvantages when compared to the criteria for selection: noncombustibility in 100% oxygen at 380 mm Hg, ability to be fabricated into a useful item, compatibility with personnel (present no dermatological problems), cost and durability. Initial problems with these materials included incompatibility with personnel, lack of sufficient material strength, cost and general unavailability. (Figure 2) The material finally chosen for the development of the uniform is a 9 oz/sq yd modified crows foot woven white Beta Fiberglas fabricated into a two piece outfit with fiberglas braid at the waist of the shirt and trousers as well as at the neck and hood closures. The sleeves and legs have a small piece of elastic inside the cuffs to hold the material tightly against the body to prevent a fire from propagating up the arm or leg. The shirt has a small piece of leather sewn to the chest to accommodate an alligator clip for the oxygen hose and communications wire. The seams are modified fell seams sewn with fiberglas thread with no loose ends exposed. The uniform is worn with cotton undershirt and shorts. These uniforms have proven successful for short "flights" to tend experimental animals as well as for long duration (32 days, continuous) human feeding studies.

The same basic material (Beta Fiberglas) and sewing techniques are used in fabricating helmets to replace leather flying helmets and in fabricating personal effects bags. The personal effects bags can be used to store necessary combustibles such as facial tissue, toilet tissue, food packaging materials, books, etc., when these materials are not in use. A slightly different 6 oz/sq yd fiberglas material is used in sheets, pillowcases, blankets, mattress covers and seat cushions. The stuffing in the pillows, mattresses and cushions is woven and matted fiberglas with a small amount of organic binder. This organic binder will burn, however, it is improbable that a fire could penetrate the outer layers of such articles to ignite the binder. Kapton or Teflon insulation has proven effective on electrical wiring.

Some combustible materials have not been replaced either because the degree of hazard presented is small or because no satisfactory substitutes have been found. Some of these items include shoes, socks, oxygen hoses and masks and wooden shavings for animal cages.

REMOVAL OF IGNITION SOURCES primarily entailed modification of the chamber electrical systems. Electrical power is used in the chambers for illumination, environmental control systems, atmospheric sample pumps, fire extinguishing system detectors and for various experimental devices such as treadmills and performance measuring devices. Electrical power is brought into the chambers through a fuse box and then cannon plugs to a junction box. From the junction box it is transmitted in either Teflon or Kapton insulated wiring protected by conduit or cable tray to its point of use. The wiring is derated by a factor of two. All switching which cannot be accomplished external to the chamber is hermetically sealed. Only those electrical devices which are essential to the experiment in progress are permitted within the chamber. In some chambers where devices which potentially overheat are not readily visible, an overheat detection and alarm system has been installed.

It should be recognized that it is impossible to remove all combustible materials and all ignition sources from oxygen enriched atmospheres used in human experimentation or operations.[3] Indeed, the hair on the surface of the human body is combustible. To cope with this potentiality, a fire extinguishing system using water as the extinguishing agent has been designed, fabricated and tested. This system will extinguish fires in cotton materials in 100% oxygen at 1 atmosphere. Such a fire extinguishing system has been installed in 13 Aerospace Medical Division space environment simulators and is programmed for installation in four additional simulators.

THE FIRE EXTINGUISHING SYSTEM consists of three basic integrated subsystems -- fire detection, control circuitry and extinguishing. The detection subsystem uses an ultraviolet (UV) light detector (Figure 3) which sends a signal into the control subsystem when light in the UV (1900Å-2900Å) region is emitted by the fire. Smoke detectors (Figure 4) using either the ionization or the light path occulsion technique are also used to sound an alarm. The UV detector is less sensitive to false activation than other rapid response detectors (such as infrared detectors) and the smoke detector could give an alarm of an overheat and impending fire condition. Other types of detectors such as preset temperature or rate of temperature rise do not have the needed response time.

The signal from the smoke detector is routed through the control circuitry to energize only visual and audible local alarms due to the possibility of false activation of the detector from fog (produced as a result of rapid decompression of the chamber) or from several other nonfire conditions. (Figure 5) The signal from the UV detector is routed through the control circuitry and performs several functions. If the control circuitry is in the "manual-electric" mode, visible and audible local alarms are energized and a light which designates the "sensing" detector is energized. The chamber operator or the chamber occupants can then decide whether or not to flow the water. If the water flow is actuated, the functions described in the "automatic" mode occur. If the control circuitry is in the "automatic" mode, electrical power to the chamber (other than emergency illumination, communications and fire detectors) is deenergized, normally closed solenoid valves are opened to initiate the water flow, local audible and visual alarms are energized, the Base Fire Department and Dispensary are summoned and a 20 second timer is energized. After 20 seconds have elapsed the water is automatically turned off and the system resets itself within 5 seconds for a second application, if necessary. The control circuitry has other alarms which alert the chamber operator to such conditions as low water pressure, inoperative fire detectors, low battery power (backup power mode), valves in the wrong position, etc. "Manual electric" mode switches for initiating the water flow are located at the chamber operator's console as well as within each compartment of the chamber. The control circuitry is designed so that the detectors and alarms can be tested without flowing water.

The water extinguishing subsystem is supplied either from the base water distribution system or, if the demand cannot be satisfied, from a pressurized tank. (Figure 6) The system is designed to flow at the rate of 7.5 gallons per minute per square foot of chamber floor area[4] through a series of nozzles to disperse the water in a spray/fog so as to cover the horizontal and vertical planes from both directions. If a pressurized tank serves as the source, it should have sufficient capacity for at least two and preferably three 20 second applications. The water extinguishing subsystem is integrated with the detectors and control circuitry so that initial water flow occurs within 0.2 seconds subsequent to the initial appearance of flame within the chamber. The water flow is stabilized at maximum rate within 0.5 seconds. (Figure 7) To meet this criterion the water is piped from the source into the chamber and through the distribution system inside the chamber to differential hydraulic pressure valves which are located adjacent to each nozzle. (Figure 8) Locating the valve adjacent to the nozzle decreases the distance the water must flow subsequent to opening the valve and thus decreases the reaction time. The control pressure on the opposite side of the valve is taken from the same water source so that fluctuations in the supply pressure will not falsely activate the system. The water flow is initiated by a signal from the control circuitry subsystem energizing a normally closed solenoid valve in the control line. This decreases the control pressure and the hydraulic valve opens permitting the water to flow. When the solenoid valve is deenergized the control line pressure increases and closes the valve thus stopping the water flow. The control line pressure can also be released by either of several strategically located manually activated quick opening ball valves so that the chamber can be protected even if all electrical power is lost.

Several fire extinguishing systems of this basic design have been tested subsequent to the initial research and development in 1967. The reaction times and water flow rates have proven effective in extinguishing fires in 100% oxygen at pressures up to 600 torr. Although the water flow rate is approximately 10 times as much as is designed for extreme fire hazards in commercial warehouses no difficulty with human compatibility has been experienced.

(Motion picture - 2 minutes in duration)

GOOD PRACTICES IN OPERATION, maintenance and training are similar to those established for aircraft by the Air Force. These include definitive assignment of responsibility, standardizing operating and maintenance procedures, maintaining updated schematics, flow diagrams and wiring diagrams for each chamber, periodic exercising emergency procedures and providing sufficient formal and on-the-job training.

Thirteen Aerospace Medical Division chambers have been modified as described above and have returned to commissioned status. Attached is a list of general requirements each of these chambers had to meet to be recommissioned. The modifications have proven effective.

GENERAL REQUIREMENTS for "manrated" chambers using oxygen enriched atmospheres.

1. Potential ignition sources should be minimized.

2. All electrical wiring should be protected from cuts, abrasions, or other damage by conduit, metal troughs, etc.

3. All electrical equipment should be grounded.

4. No convenience electrical outlets should be allowed in the chambers.

5. Insure that fuses are of proper rating and type.

6. All electrical switching should be accomplished external to the chamber. If this is not possible, switches should be hermetically sealed.

7. All unnecessary combustibles should be removed.

8. Clothing and bedding for personnel in the chambers should be noncombustible.

9. All internal wiring should be insulated with Teflon or equivalent.

10. Fire extinguishing systems should be provided.

11. Definite responsibility for the chambers should be assigned at the daily chore level for operations and maintenance procedures.

12. Updated schematics, flow diagrams and wiring diagrams for each chamber should be maintained.

13. SOP's should be short, to the point and verified for eacn experiment.

14. Standard procedures for keeping and maintaining operations, maintenance and training logs should be established.

15. Medical review of chamber operation and medical surveillance should be definitized.

16. An emergency medical treatment area should be provided.

17. Emergency procedures and systems should be short and easily accomplished.

18. Back-up emergency power should be provided.

19. Provisions should be made for both internal and external emergency recompression.

20. A communications system should be provided.

21. Each experiment protocol should be reviewed and approved by a laboratory board prior to implementation.

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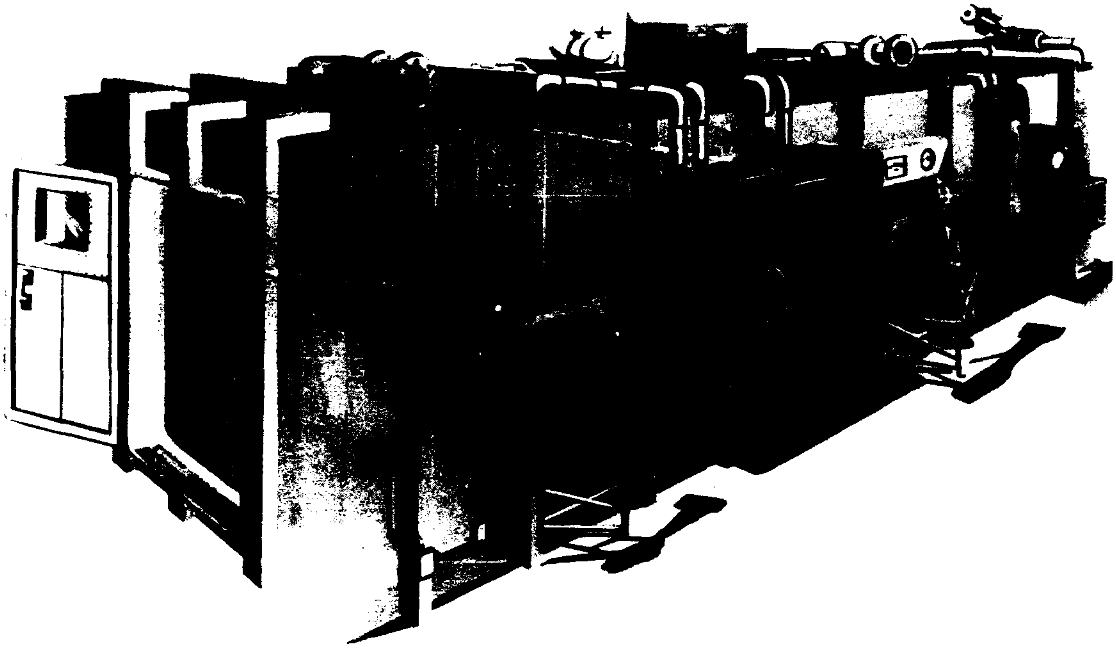

Fig.1 Typical space environment simulator

Fig.2 Beta fiberglas uniform

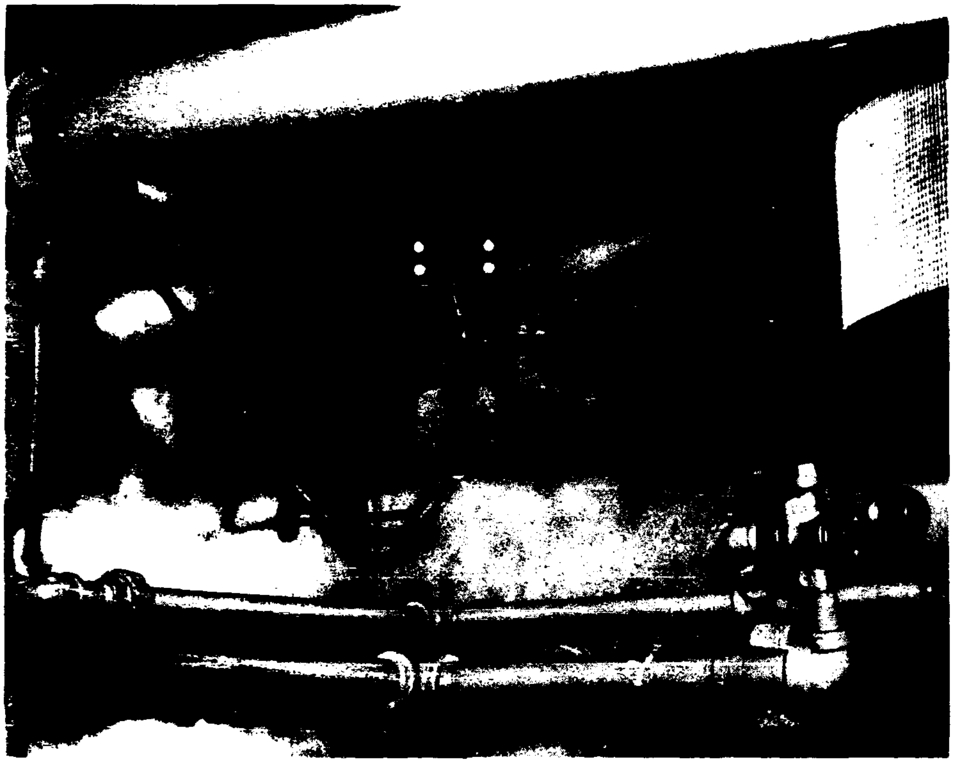

Fig.3 UV detector

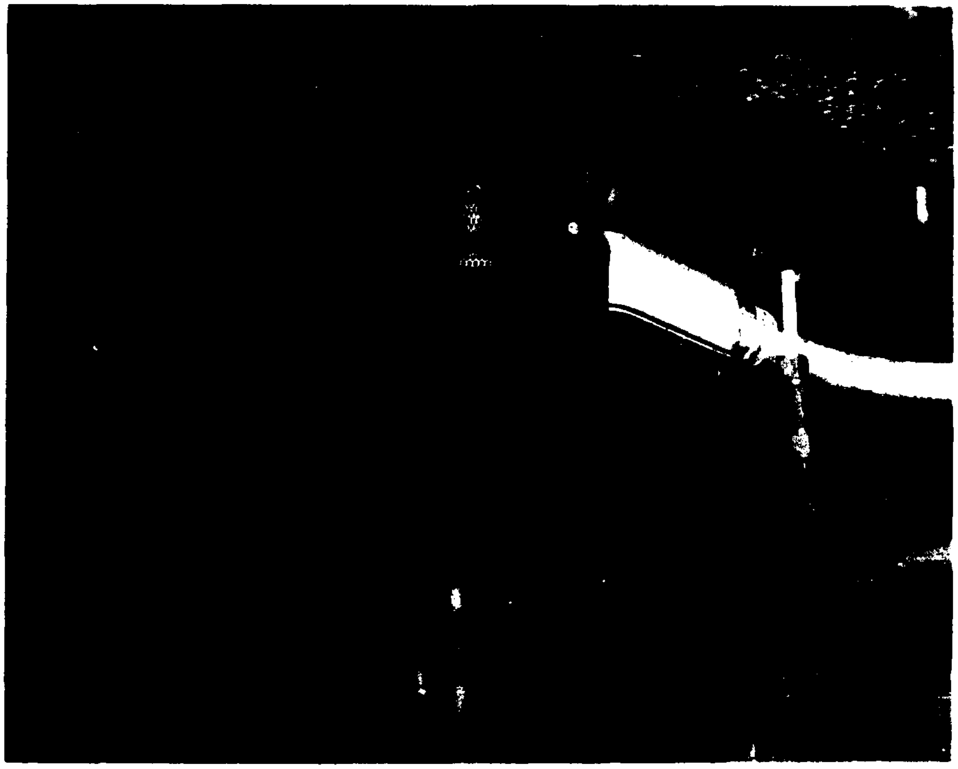

Fig.4 Smoke detector

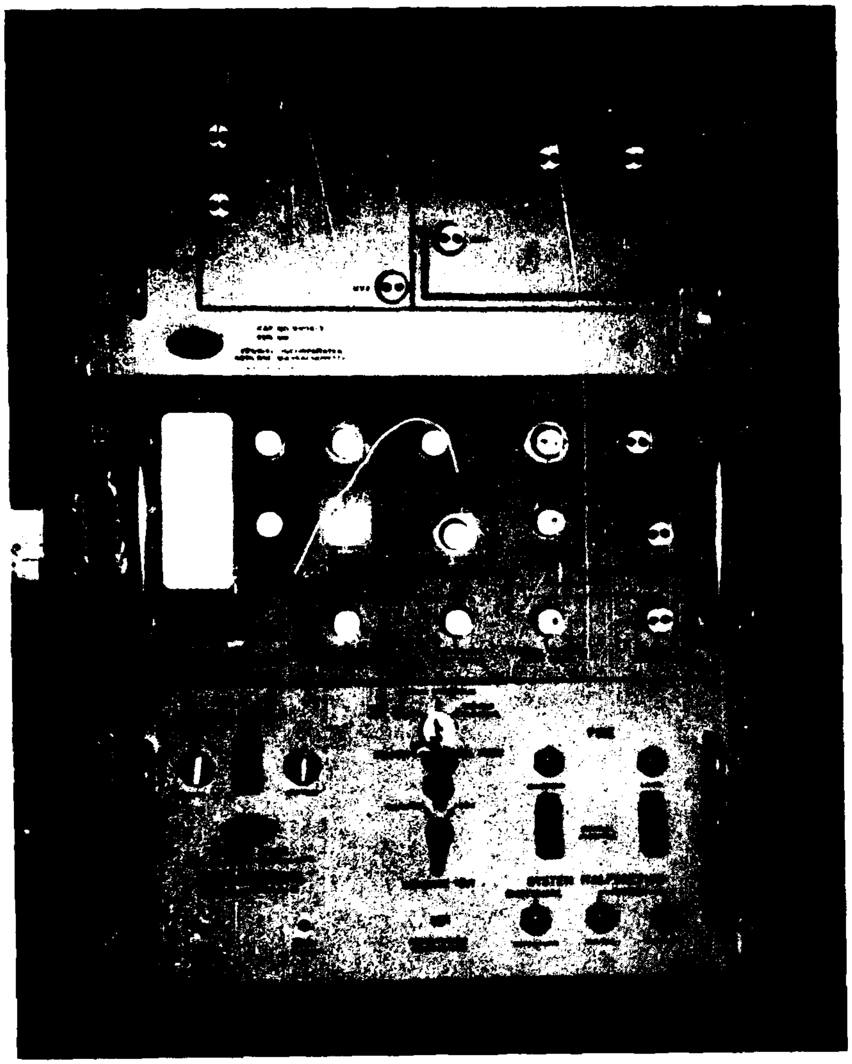

Fig.5 Fire extinguishing system monitoring console

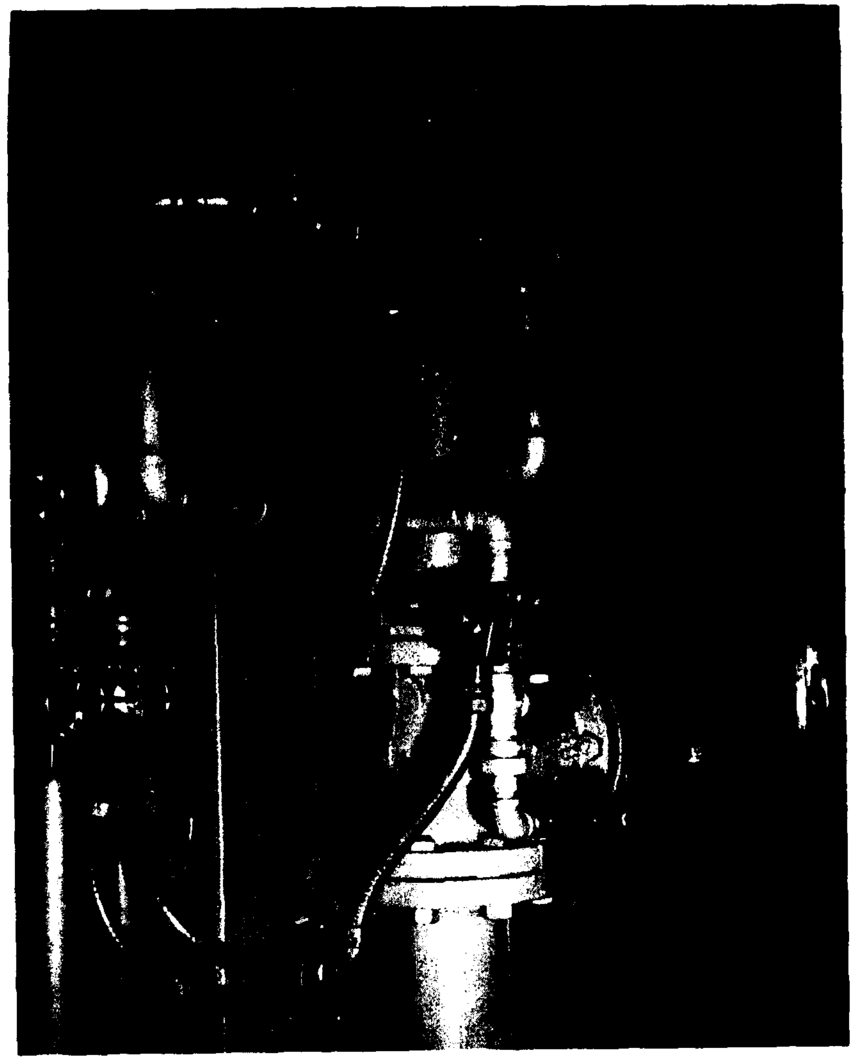

Fig.6 External water supply system

Fig.7 Internal water distribution system

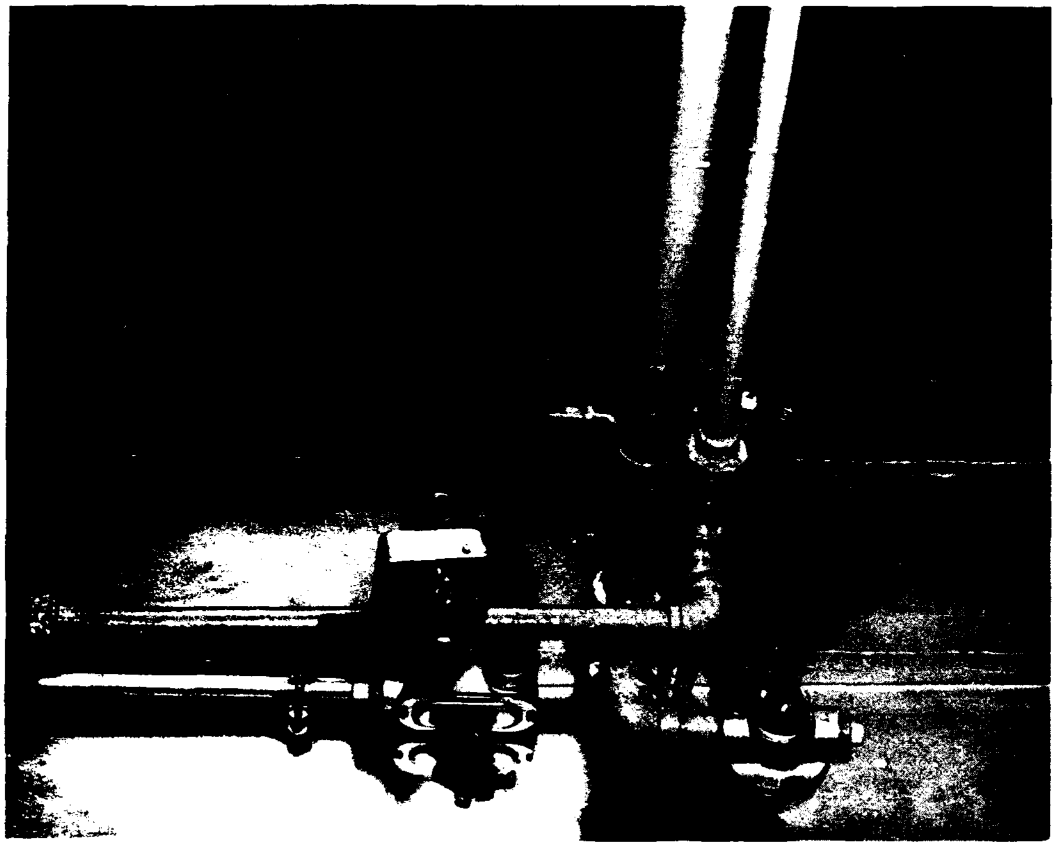

Fig.8 Valve and nozzle

INFLUENCE DES VARIATIONS D'UN CHAMP MAGNETIQUE SUR LA CROISSANCE DE CERTAINS MICRO-ORGANISMES

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- Dans la première partie de l'expérience où le champ magnétique est crée, les courbes témoins et expérimentales sont pratiquement confondues après la phase de latence ou "lag", le temps de doublement d'une bactérie est, dans les deux cas, de 87 mn.

- Dans la seconde partie de l'expérience, qui correspond à la suppression du champ, on note, dans la quinzaine de minutes suivant sa chute, une augmentation brutale du nombre de bactéries dans les lots expérimentaux. Le temps de doublement passe alors, pour ceux-ci, à 20 mn. alors que celui des témoins reste inchangé.

- Dans la dernière partie, qui correspond à la remise sous champs des échantillons expérimentaux, on observe qu'après cette phase de croissance très rapide, leur courbe, après l'ébauche d'un plateau, tend à devenir parallèle à la courbe témoin; le temps de doublement est alors de 95 mn, alors que celui des témoins reste à 87 mn.

On a donc l'impression que le champ magnétique a peu d'action par lui-même sur le taux de croissance des bactéries; par contre, il semble que sa variation brutale dans le temps entraîne une augmentation brusque de ce taux. Afin de vérifier ce deuxième point, une seconde série d'expériences est entreprise.

Dans celle-ci, la souche bactérienne est utilisée 3 heures et demie après son ensemencement de facon à se trouver déjà dans sa phase de croissance exponentielle et à ne pas être gênée par la phase de latence. On expose le lot expérimental pendant 4 mn seulement à l'action du champ magnétique, puis celui-ci est interrompu dans les mêmes conditions que précédemment, mais contrairement à la série antérieure, on ne le rétablit pas. On suit pendant 100 mn l'évolution du taux de croissance tous les échantillons étant maintenus à la température constante. Toutes les 20 mn, on prélève une ampoule et on effectue le comptage des bactéries viables.

Courbe 2 - L'étude des courbes de croissance permet de retrouver le même phénomène avec ses trois phases.

Alors que pendant toute l'expérience le temps de doublement des bactéries témoins reste à 47 mn, celui des bactéries expérimentales, d'abord identique au précédent, passe à 20 mn; il reprend sa valeur initiale après un plateau plus nettement marqué que dans la série précédente.

Pour complèter cette étude, une troisième série a été entreprise en faisant varier plusieurs fois, au cours de la même expérience, la valeur du champ magnétique. Les techniques bactériologiques utilisées ont été les mêmes, seuls les prélèvements ont été plus fréquents (toutes les 10 minutes). Le lot expérimental a été soumis à l'action du champ magnétique pendant trois périodes de 12 mn, 75 mn.et 75 mn. séparées par deux interruptions de 13 mn. et de 75 mn.

Dans ces conditions, on observe (Courbe 3)

- Dans les minutes suivant les variations rapides du champ magnétique: une augmentation de la vitesse de division (respectivement 29 mn., 24 mn. et 24 mn.), alors que la courbe-témoin montre une vitesse de doublement stable, de 48 mn.

L'augmentation de la vitesse de croissance est suivie par un plateau survenant quelle que soit la valeur du champ magnétique et tendant à ramener la courbe expérimentale sur la courbe-témoin.

CONCLUSION

L'ensemble de ces trois séries d'expériences semble confirmer que la présence d'un champ magnétique de 42,000 gauss ne perturbe en rien le taux de croissance d'Escherichia Coli puisque des courbes similaires de croissance sont obtenues, que les bactéries soient ou non placées dans le champ.

Par contre, la variation brutale de ce champ semble provoquer des modifications métaboliques au niveau de la bactérie qui se traduisent, dans les minutes qui suivent cette variation, par une augmentation brusque du taux de croissance évalué par le nombre de bactéries viables.

Il est à remarquer que, dans toutes les expériences, le temps de doublement obtenu lors de ces périodes de croissance accélérée, est pratiquement constant et de l'ordre de 25 minutes, ce qui est proche de la durée minimale de replication du D.N.A. bactérien pour la souche considérée.

Tels sont les résultats bruts de nos expériences. Il est bien évident que leur interprétation n'est pas simple et pose de nombreux problèmes. En particulier, sachant qu'en phase exponentielle de croissance, les bactéries sont "polynucléées" et ont deux ou quatre "noyaux", se pose la question de savoir si l'augmentation observée du nombre de bactéries viables correspond à une division cellulaire complète (division cytoplasmique associée à une division "nucléaire"), les bactéries filles ayant alors le même nombre de noyaux que la bactérie mère; ou bien, s'il s'agit d'une simple division cytoplasmique

La mise au point par les Centres de Recherches de Physique de champs magnétiques continus de plus en plus intenses dépassant les 100,000 Gauss et de champs pulsés atteignant 1,000,000 pendant 20 µsec, permet d'envisager d'ores et déjà des applications tant scientifiques (physique corpusculaire - physique du solide) qu'industrielles. Sur le plan biologique se pose alors la question de leur action sur les organismes vivants.

L'étude bibliographique de ce sujet révèle de nombreuses contradictions dans les résultats obtenus; mais une analyse plus fine des protocoles expérimentaux montre que les conditions changent d'une expérience à l'autre, du fait de nombreux paramètres en cause, tant physiques que biologiques. De facon à réduire ceux-ci au minimum, nous choisissons un phénomène simple et reproductible: l'étude de la courbe de croissance d'une bactérie soumise à une variation donnée de champ magnétique, cette étude n'étant que la première étape d'une expérimentation plus complète.

MATERIEL ET METHODES

Sur le plan biologique

La souche bactérienne utilisée est une Escherichia Coli, PA 309 résistante à la streptomycine, auxotrophe pour la Thréonine, la leucine, l'histidine, l'arginine et le tryptophane, déficiente en vitamine B_1.

On ensemence 1 ml d'une culture de 18 heures, arrivée en fin de phase exponentielle de croissance, dans 100 ml de bouillon Luria. Après agitation, on le répartit en ampoules scellées de 1 ml.

On divise aléatoirement l'ensemble de celles-ci en 2 groupes identiques. Le premier servant de témoin ne subit aucune agression physique, le second est placé dans l'entrefer de la bobine produisant le champ magnétique.

Les deux lots sont maintenus à une température constante et identique tout au long de l'expérience grâce à un système de thermostatation. On choisit volontairement une temperature assez basse, 24° ou 26°, de facon à augmenter le temps de croissance, donc à étaler les courbes, et ainsi à faire mieux ressortir les éventuelles différences entre les séries témoins et expérimentales.

A intervalles de temps réguliers, une ampoule de chaque lot est ouverte, et on procède à la numération des bactéries viables par la méthode des dilutions successives et d'étalement sur boites de Petri contenant une gélose Luria. Pour chaque échantillon, on ensemence plusieurs boites avec plusieurs dilutions successives de facon à pouvoir réduire au mieux l'écart type.

Sur le plan physique (Figure 1)

Le champ magnétique est crée par un aimant supraconducteur autour d'un canal transversal offrant une section de 2 x 4 cm dans lequel sont placés les échantillons expérimentaux. L'aimant est constitué de deux bobines en fil de Niobium-Zirconium refroidies à $4{,}2^{\circ}K$ par immersion dans de l'hélium liquide; dans ces conditions, l'alliage devient supraconducteur ce qui permet le passage, sans résistance interne, d'un courant de 180 ampères. Ainsi est réalisé dans le canal transversal un champ magnétique de 42,000 gauss, continu et uniforme, puisque la variation de champ est inférieure à 5 p. 100 jusqu'à 34 mm, de part et d'autre du centre du canal. L'hélium est maintenu dans un cryostat pour réduire au minimum son évaporation. Les dimensions de l'ensemble de l'appareil sont relativement réduites: 250 mm de diamètre et 500 mm de hauteur.

La mise sous champs ne peut être effectuée dans les conditions actuelles que très progressivement en 6 mn, ce qui fait une variation de champ magnétique dans le temps de ($\Delta B/\Delta t$) de l'ordre de 116 G/sec.

Par contre, l'interruption brutale de l'alimentation par blocage thermique, permet une rupture de champ très rapide, celui-ci passant de 42,000 gauss à une valeur résiduelle de quelques gauss en 400 msec., soit un $\Delta B/\Delta T$ égal à 105,000 G/sec.

RESULTATS

Dans une première série, la sourche bactérienne est utilisée immédiatement après son ensemencement, de facon à être en phase de croissance expérimentale. Le lot expérimental est exposé pendant 130 minutes à l'action du champ magnétique, puis on interrompt celui-ci brusquement selon les modalités décrites plus haut. 35 minutes après l'arrêt du champ, on le rétablit jusqu'à la fin de l'expérience, soit pendant 5 heures.

Tous les échantillons tant expérimentaux que témoins sont maintenus à température constante. Toutes les demi-heures, on prélève une ampoule de chaque lot et on effectue le comptage des bactéries viables.

Courbe 1 - L'examen de la courbe-type de croissance nous montre que:

sans réplication immédiate des "chromosomes" bactériens; dans ce cas, les bactéries filles auraient un nombre de noyaux inférieur à celui de la bactérie mère.

Par ailleurs, reste à expliquer le mécanisme d'action de la variation de champ magnétique. Des expériences complémentaires utilisant des métabolites radio-marqués permettront peut-être, de résoudre ces problèmes.

Ces résultats, se rapprochent d'une certaine facon de deux que nous avions rapportés à la 21ème réunion de l'AGARD, à Lisbonne en 1964, où nous avions montré que des champs hyperfréquences (ou radar) augmentaient le métabolisme de certaines cellules.

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* Travail du Groupe de Biophysique du Centre de Recherches de la C.G.E. et du Laboratoire de Biologie Aérospatiale du C.E.R.M.A.

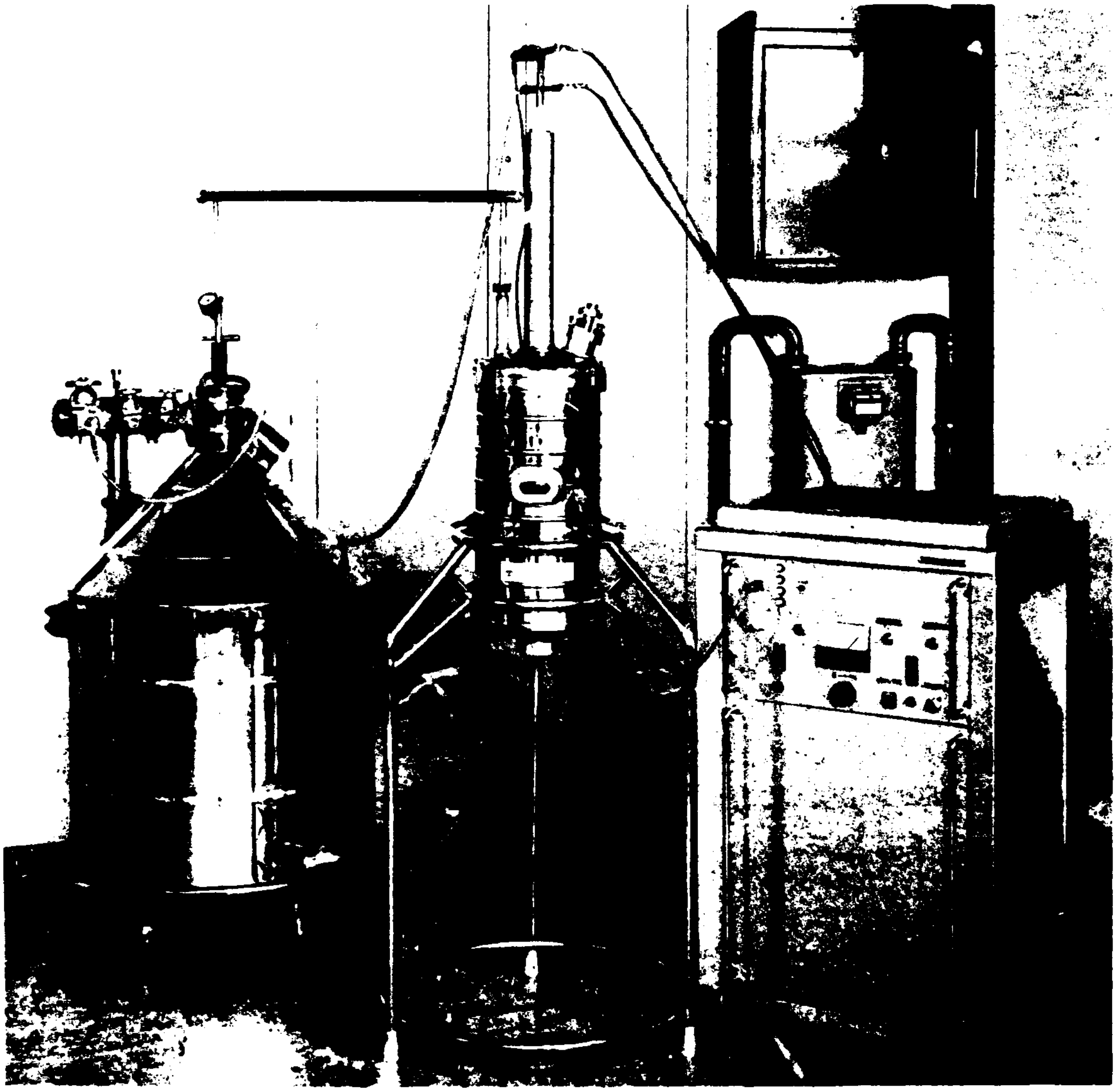
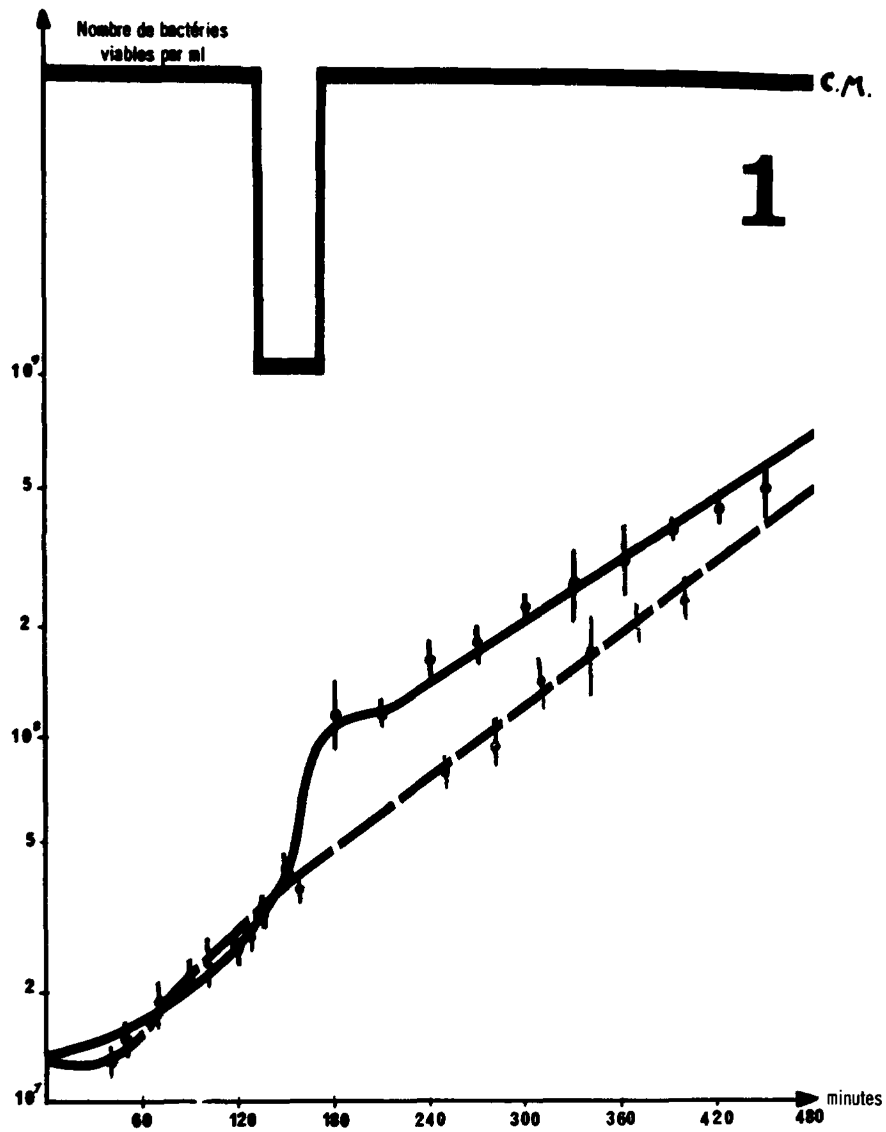
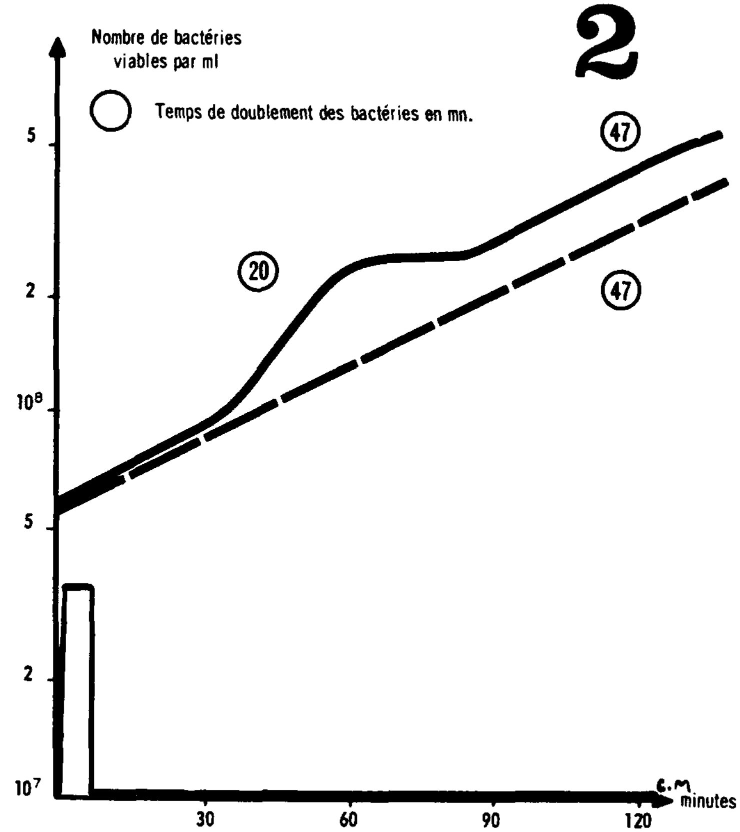


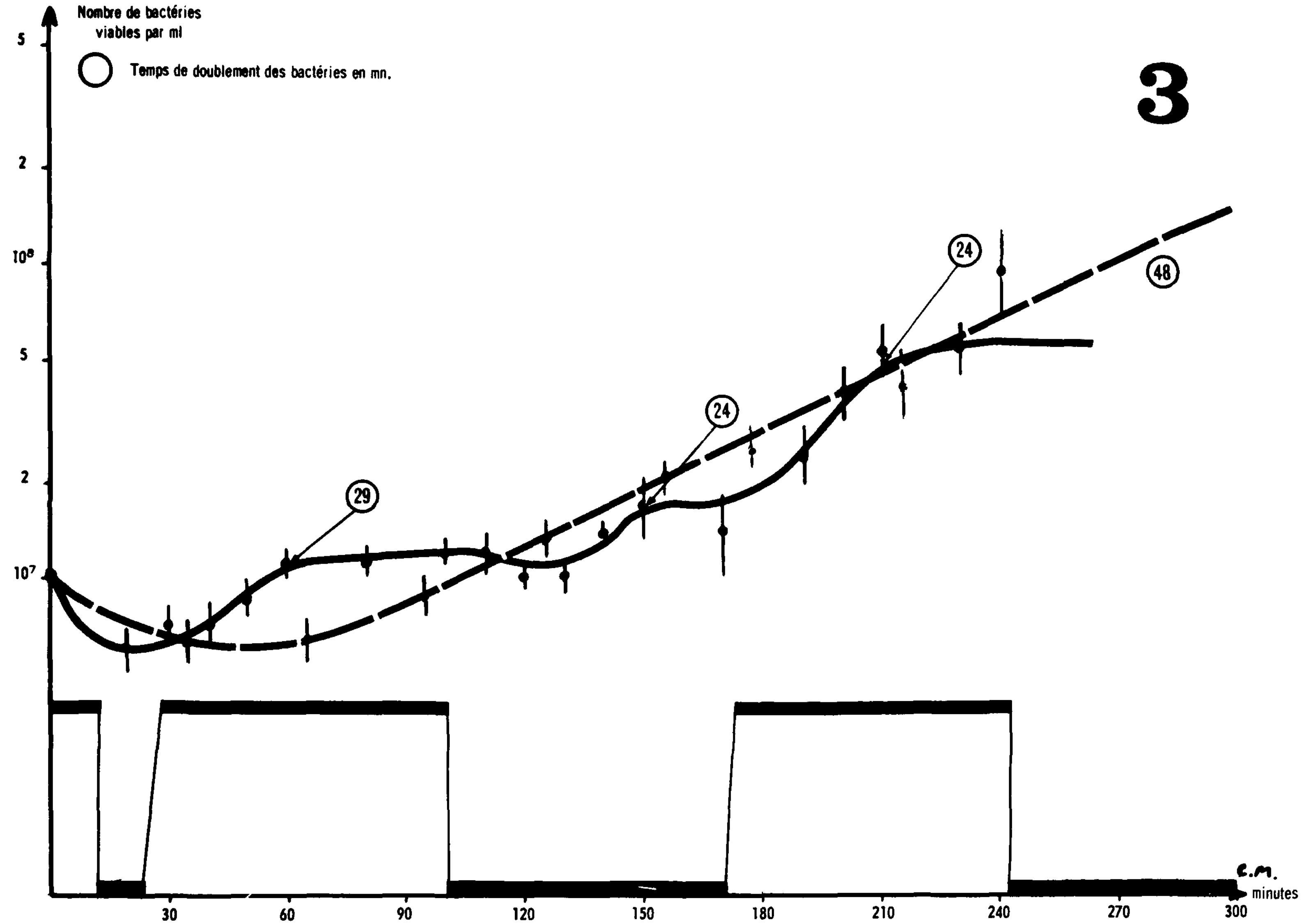
Figure 1

ENSEMBLE DU DISPOSITIF D'EXPERIMENTATION :

de gauche à droite : le container d'Hélium liquide, le champ magnétique supraconducteur dans son cryostat, l'alimentation.


Nombre de bactéries viables par ml
C.M.
1
10^9
5
2
10^8
5
2
10^7
60
120
180
240
300
360
420
480
minutes


Nombre de bactéries viables par ml
2
Temps de doublement des bactéries en mn.
47
20
47
5
2
10^8
5
2
10^7
C.M.
30
60
90
120
minutes


3
Nombre de bactéries viables par ml
Temps de doublement des bactéries en mn.
5
2
10^8
5
2
10^7
29
24
24
48
30
60
90
120
150
180
210
240
270
300
minutes
C.M.

AEROMEDICAL

EVACUATION

Wing Commander D.W. Atkinson

Headquarters Air Support Command

Royal Air Force

SUMMARY

THE PURPOSE of this paper is to outline the arrangements in the Royal Air Force for strategic and tactical aeromedical evacuation and to describe some of the equipment which has been developed for the task.

AIRCRAFT flown on RAF scheduled aeromedical flights from Singapore, Bahrein and Germany as well as those used for the UK internal flights are described. The problems of non-scheduled flights, communications and certain medical categories involved, are mentioned.

EQUIPMENT is briefly described under the following headings:

a. Light Alloy Stretcher

b. New East Radcliffe Respirator

c. Blease Automan Resuscitator

d. RAF turning frame

e. Mechanical and electrical suckers.

AEROMEDICAL EVACUATION UNITS have been developed for tactical operational use. These units are self contained in personnel and equipment including transport. Their role is to evacuate not to treat casualties. Equipment is described under the following headings:

a. Tentage

b. Generator and lighting

c. Cookset/Steriliser

d. Lightweight containers

e. Vehicles

AEROMEDICAL EVACUATION (D1)

Wing Commander D. W. Atkinson, Deputy Principal Medical Officer (Air)
HQ Air Support Command RAF

THE PURPOSE of this paper is to outline the arrangements in the Royal Air Force for strategic and tactical aeromedical evacuation and to describe some of the equipment which has been developed for the task.

STRATEGIC AEROMEDICAL EVACUATION

In order to preserve flexibility in the use of its transport force, the RAF has no aircraft used wholly for aeromedical purposes. All RAF transport aircraft can be partially or completely roled to carry stretchers (litters). Every routine passenger or freight aircraft carries stretcher equipment to permit the emergency transport of two or three stretcher patients.

SCHEDULE AEROMEDICAL FLIGHTS are however flown every week to the United Kingdom from Singapore or from Bahrein, calling at intermediate stations en route. A weekly service is flown from Germany. The aircraft of Air Support Command used on these routes are as follows:

BRITISH AIRCRAFT CORPORATION VC 10 is a four engined jet aircraft employed on the Singapore-UK route. It can carry up to 72 stretchers or 136 seated patients but as normally roled, 9 stretchers, 30 seated patients and some 60 passengers are carried.

BRISTOL BRITANNIA MK 1 is the oldest of the RAF's strategic aircraft. The turbo-prop Britannia accepts 53 stretchers or 110 seated patients. Standard scheduled loads from Bahrein through Cyprus and Malta are up to 16 stretchers and 65 seats.

AVRO ANDOVER C MK 1 provides a weekly lift from Germany of 9 stretchers and 16 seated patients. The twin turbo-prop Andover will accept a maximum load of up to 18 stretchers or 44 seats.

UK INTERNAL FLIGHTS are undertaken by Pembroke fixed wing aircraft and by Wessex or Whirlwind helicopters. The Pembroke is the only unpressurised aircraft used for aeromedical evacuation and has a load capacity of 6 stretchers or 7 seats. More often than not it is used to transport a single case with suitable escorts. The Wessex helicopter accepts up to 8 stretchers or 16 seats whilst the Whirlwind has a shorter range and can take only 6 stretchers or 9 seats; again the maximum capacity is very rarely used as space for nursing patients would be very restricted.

WITH THE VC 10 INTRODUCTION in May 1967, a mixed aeromedical/passenger load was scheduled routinely. An aeromedical ward concept was therefore introduced with the forward part of the aircraft screened off from the remainder of the seated patients and passengers, to provide a stretcher compartment.

IN EMERGENCY, a special aeromedical flight can be mounted from the UK. In practice however, it is most uncommon for this to be necessary. Communications are so effective and the Air Support Command fleet so active that there is almost invariably a suitable aircraft within easy reach of any overseas military theatre. These aircraft are controlled by the Operations Centre at Air Support Command Headquarters which is of course continually manned. A duty medical staff officer at the Headquarters is able to arrange to divert a suitable aircraft where it is required.

COMMUNICATIONS are normally made by means of signals messages, but there is teleprinter link between the Operations Centre and all overseas staging posts on the route to the Far East. Single side band equipment permits voice communication with aircraft in flight over a wide range. For example, medical advice has been passed between Upavon, in Southern England, and the captain of an aircraft on an aeromedical flight over the East Mediterranean. The clarity of speech was comparable with a long distance telephone call. An efficient communications system is the key to an efficient aeromedical service. It is because of a lack of our normally excellent direct communications that unusual off-route special flights occasionally cause problems. This occurred recently when we sent an Andover to SW France to collect a British soldier injured there. A 24 hour delay in returning the patient home occurred due to a misunderstanding caused by communication difficulty.

OTHER AIRCRAFT in use in the Command which may be converted to carry aeromedical patients are:

COMET 4, four engined jet aircraft which are now rarely used for aeromedical flights, having been replaced by the VC 10. They can however carry 12 stretchers and 46 seats per aircraft.

ARGOSY four engined turbo-prop; this is a tactical aircraft with a capability of conversion to take 48 stretchers or 72 seats.

HERCULES (C130) of which the RAF now has a substantial number. This American type accepts either 74 stretchers or 92 seats or a combination of both.

BELFAST is basically a freight carrier; this aircraft would only be used to carry patients in an emergency.

THE EMERGENCY CASES which provide the bulk of our more difficult special aeromedical flights come from the following categories:

a. Spinal Injury.

b. Renal Failure.

c. Multiple injuries.

SPINAL INJURY in serving personnel overseas is frequently due to a motor accident, diving into shallow water or even into empty swimming pools. In the absence of respiratory paralysis, patients can be transported with minimum delay nursed on the RAF turning frame to which reference is made later. Where respiratory paralysis accompanies a high level spinal fracture, the problems are of course greater. Not only has the patient to be nursed on a turning frame but his respiration requires mechanical support. In the RAF, the Radcliffe Intermittent Positive Pressure Respirator is used and operated by an anaesthetist who invariably leads the specially trained aeromedical team. This team, with its equipment, can be despatched from the UK at short notice. For example on Christmas Eve 1967 a message was received from the Far East asking for a team to transport a patient with a spinal lesion. The team was on its way by 1500 hours on Christmas Day by civil aircraft. The patient returned subsequently on one of our VC 10's. Ideally, the team is given at least 48 hours at the destination hospital to assess the patient's fitness to fly and to give him confidence in the team and their equipment. The team also has time to recover from what may have been a long outbound trip. If the team leader considers it in the patient's interest to delay the return flight for a further period he is able to arrange this through Air Support Command Headquarters. On arrival in the UK, helicopter transfer from airfield to hospital is invariably arranged. The National Spinal Injuries Centre at Stoke Mandeville is extremely cooperative in accepting service cases and a helicopter landing pad is available there.

RENAL FAILURE may be due to primary renal disease or secondary to trauma. The RAF has used artificial kidneys for many years and the renal machine from our hospital at Halton has several times been dispatched to overseas theatres to dialyse cases of acute renal failure. The aim is normally however to recognise the onset of renal failure at an early stage and to transport the patient to the UK for treatment at the renal unit. The case of a Royal Marine NCO illustrates this. This man sustained multiple injuries due to the explosion of a 3 inch mortar fuse while operating in the Arabian Peninsula. There was the virtual loss of the right leg, right arm and left hand with massive injuries to the face, left leg and anterior aspect of the body. Oliguria developed after transfer to Aden for surgery and in the absence of a renal unit ten peritoneal dialysis cycles were performed. Next day he was emplaned on a VC 10 and during the flight to the United Kingdom a further 14 peritoneal dialysis cycles were carried out. On arrival in England he was transferred to the RAF renal unit by helicopter. A total of 26 haemodialyses, that is on the artificial kidney, were required before the patient was out of danger. He made a good recovery considering his primary injuries with little impairment of renal function.

MULTIPLE INJURIES may be due to explosives or to motor vehicle accidents, depending on the theatre involved and the state of military activity. Cases of extensive injury have frequently been successfully transported by air; our busiest period in recent times was during the withdrawal from Aden. The case of the Royal Marine NCO already cited illustrates the extent of injuries encountered. Another example was that of six soldiers injured in a military reconnaissance vehicle in North Africa. They suffered extensive burns and various injuries and were conveyed to Malta by an Argosy of the Near East Air Force, transferred to the UK by an Air Support Command Britannia and to hospital by two helicopters. The whole operation went smoothly because of good communications.

A further example concerns an Army signaller who was transferred from Paris to Northolt, after a road accident in which he sustained left radial nerve paralysis, chest injury complicated by empyema, fractured pelvis, fractures of the left femur, tibia and humerus. A medical team of six including a surgeon, anaesthetist and two nursing sisters was dispatched in an Andover to escort him. There were no problems on this particular flight.

AEROMEDICAL EQUIPMENT

a. Light Alloy Stretchers. We have been developing a lightweight stretcher for aeromedical use for over a year and are now about ready to go into production. The final product is in magnesium alloy with a woven terylene cloth bearing surface. Total weight is only 12 lbs ($5\frac{1}{2}$ kilograms). Rigid cross bars were found to be necessary for adequate strength and these are detachable for stowage of the stretcher; we see no need for really rapid erection of an aeromedical stretcher. It is, of course, made to Stanag 2040 dimensions. At least one stretcher will be tested to destruction at the Royal Aircraft Establishment.

b. New East Radcliffe Respirator. Mention has already been made of the use of positive pressure equipment in transporting cases of respiratory paralysis by air. Our present respirator has the following disadvantages:

(1) It weighs 450 lbs (204.5 kilograms).

(2) It consists of separate pump, humidifier and batteries.

(3) It uses wet batteries for its emergency power which the regulations specify as hazardous cargo.

A new respirator has therefore been developed which is much lighter, is a single self-contained unit and employs small dry cells for its emergency electrical supply.

c. Blease Automan Resuscitator. This piece of equipment which is carried on all RAF Search and Rescue helicopters as well as aeromedical flights is a relatively simple apparatus for administering air or oxygen automatically. It operates regardless of chest size so that no harm can follow unskilled use. In our Search and Rescue helicopters, medically trained personnel are not usually carried.

d. RAF Turning Frame. The Stryker turning frame which was used in the RAF for some time for transporting spinal injury cases proved to be very bulky for use in aircraft and had no proper means of attachment within the aircraft and had to be lashed to the floor. The RAF turning frame was therefore developed to the overall dimensions of a standard NATO stretcher so that it could be carried in the air on stretcher supports; it also fits all service ambulances. Made by the Martin Baker Aircraft Company it weighs 85 lbs (38.5 kilograms) and has proved to be a successful piece of equipment. The frame can be mounted on a plinth to give a reasonable working height and all round access to the patient.

e. Mechanical and Electrical Suckers. Both of these types of sucker are in use in the RAF; the electrical equipment operates from the aircraft supply of 28 volts DC. The foot-operated Cape sucker has been found to be a simple effective instrument which is independent of electrical supplies.

TACTICAL AEROMEDICAL EVACUATION

By this term is meant aeromedical evacuation from a forward unsophisticated airstrip in an operational situation. For this role a number of Aeromedical Evacuation Units (AEU) have been formed. Each unit is self-contained in equipment and personnel and is composed of two identical, independently viable sub-units or flights. An AEU operates with an army medical unit and is intended to evacuate not treat casualties; the only treatment afforded is continuation treatment.

PERSONNEL

There are 24 personnel in each AEU (12 in each flight) including 2 doctors, 2 medical NCO's, 4 registered male nurses, 2 cooks and the remainder nursing attendants. All members of the unit are also qualified drivers.

EQUIPMENT

New equipment is continually under development.

ACCOMMODATION consists of tent units each 12 feet x 12 feet which can be combined or used singly. The tents are easily erected on a light alloy framework. They have an inner skin of white fabric which provides a light working environment.

LIGHTING is provided by a portable generator which is petrol driven. It is reliable; one generator is capable of providing sufficient electricity for the use of one AEU Flight. Special electric bulbs are used which are screwed directly into the electric cable; the method is quite safe even in wet conditions.

COOKSET/STERILISER enables the unit to feed itself and its patients. The cookset is a compact piece of equipment which gives constant hot water and which incorporates trays for sterilising instruments. It can be operated either by butane gas cylinders or petrol. It has proved an extremely safe and efficient piece of field equipment.

REFRIGERATORS are provided on a scale of one to each flight for the storage of vaccines and other perishable supplies. They are lightweight and paraffin operated.

LIGHTWEIGHT CONTAINERS are used to contain medical equipment. They consist of lightweight aluminium boxes with fitted trays, and have proved very satisfactory, but in the interests of further weight saving the use of fibreglass containers is being explored.

VEHICLES for each flight consist of a small field ambulance built on the Landrover chassis and two Landrover all purpose vehicles. Each of these two vehicles can be converted to accept two stretchers by fitting lightweight, collapsible stretcher gear.

The AEU may be transported in any tactical aircraft - for example, Hercules, Andover or Argosy. One flight with its personnel, equipment and vehicles can be carried by one Hercules.

SUMMARY

This short paper is intended to give an outline of aeromedical evacuation as operated by the Royal Air Force and also to serve as an introduction to the papers which follow.

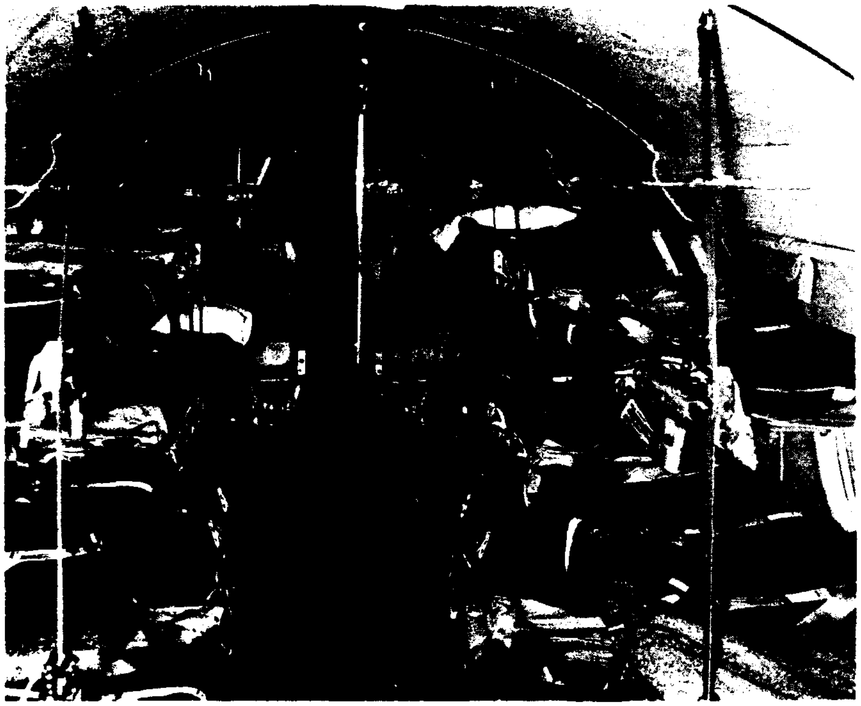


Fig.1 Interior of Avro Andover in which aeromedical patients are transported weekly from Germany to the UK

Fig.2 Interior of VC 10 showing part of stretcher compartment. The litters are supported on outriggers from the substantial removable posts

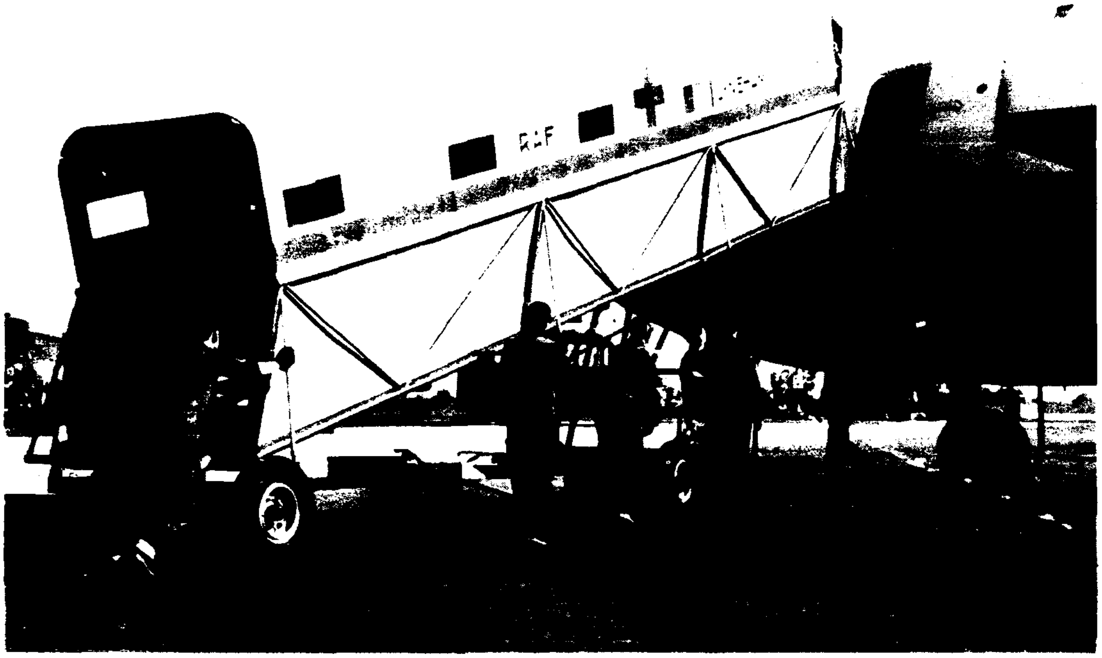


Fig.3 Unloading VC 10 with the aid of covered ramp

Fig.4 A more flexible alternative to the aeromedical ramp is the shelter raised by a fork lift truck

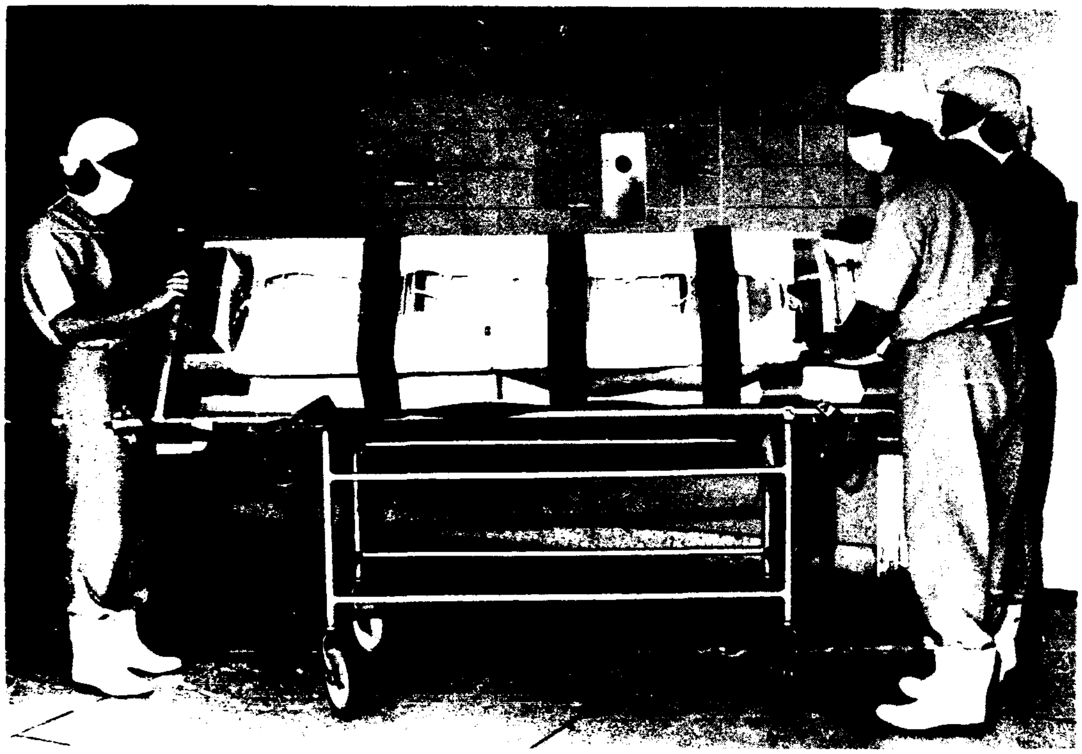


Fig.5 The RAF turning frame mounted on a hospital trolley. It is designed to fit standard NATO litter supports

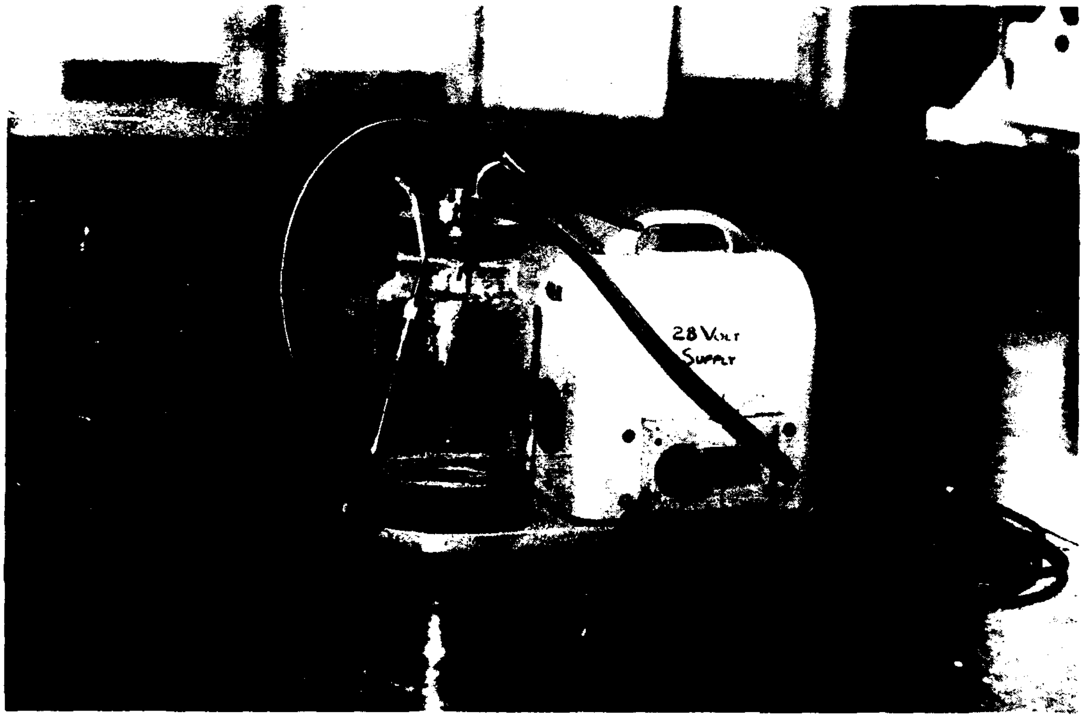


Fig.6 RAF electrical sucker for use in aircraft

Fig.7 The Cape foot-operated sucker

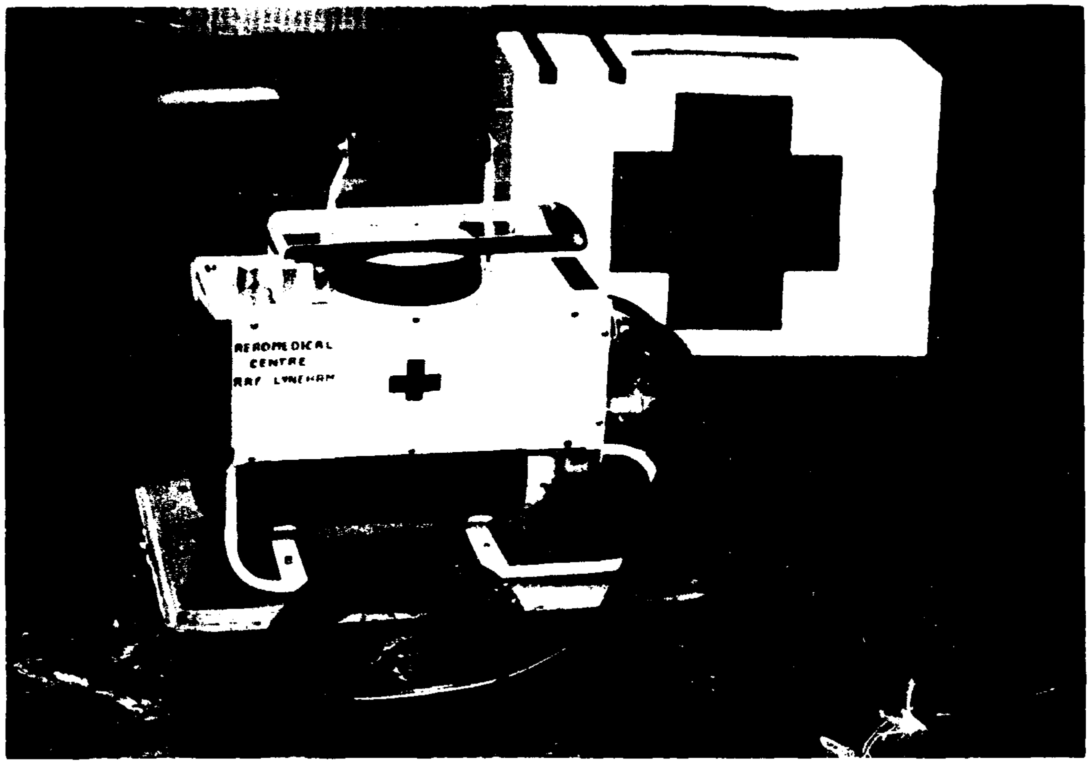


Fig.8 Blease Automan Resuscitator provides automatic respiration, manual respiration or oxygen only for spontaneous respiration

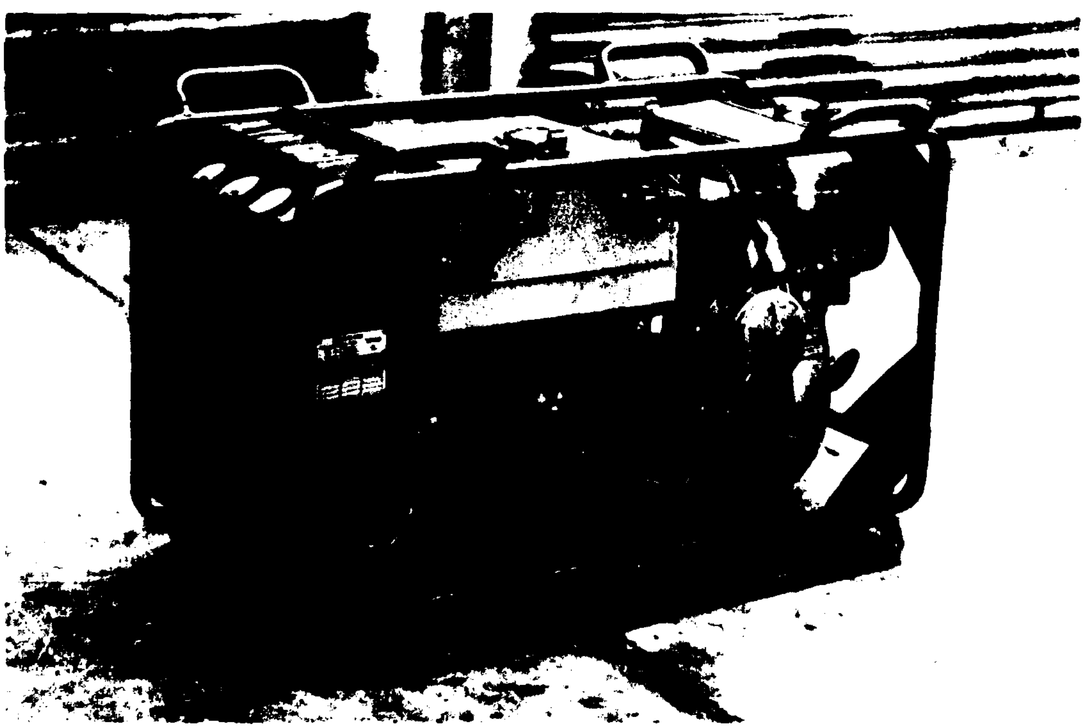


Fig.9 Petrol driven generator used to provide electrical power for aeromedical evacuation units

EXPERIENCES IN AIR TRANSPORT OF PATIENTS IN PEACE TIME

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Germany

ON ACCOUNT OF the ever-increasing density of traffic and owing to their specific flying capabilities the utilisation of helicopters for the evacuation of emergency patients is of growing importance. In comparison to emergency ambulances, helicopters have the advantage of being road-independent, thus enabling quick transport of patients. Equally important is the possibility of continuing life-saving measures whilst in flight.

I will report on thirty-five helicopter missions within the area of the University Hospitals in Düsseldorf, Germany. In the University Hospital area a helicopter landing site has been provided which, however, is not equipped with any lighting for night missions. Therefore all flights have been conducted during daylight and with good visibility. The hospitals were informed by phone of the forthcoming transfer and in most cases also of the nature of the injury.

Requests for a helicopter mostly resulted from an emergency situation requiring immediate and as-fast-as-possible transfer of the patient into a special department.

In 25 cases air transport was arranged by the hospital physician first treating the patient on account of peculiarities of the injury or sickness. Whole blood was twice flown in an emergency situation. Seven patients were flown directly from the scenes of accident to University Hospitals on the initiative both of doctors who happened to pass by or of traffic police. Thus victims of autobahn accidents were initially transported by police helicopters of the ALOUETTE II type, the subsequent transfer without exception being carried out by high-capacity helicopters of the German or Allied forces.

One disadvantage of the ALOUETTE type police helicopters is the narrow cabin, which does not allow optimal in-flight treatment required to be given to the severely injured patient indicated to prevent or treat incidents, for instance an aspirator. During transfers by means of the more spacious army helicopters, on the other hand, both medical care and attendance by medical personnel were very good on account of emergency equipment.

Shock treatment of accident victims during transportation from the scene of accident to the Hospital was mostly insufficient. But in spite of these disadvantages speedy evacuation of the injured may prove to be of life-saving importance. A 45-years old woman was flown directly to the hospital without any shock treatment after a head-on collision with her car on the autobahn. Shock treatment was started immediately following her arrival in the hospital. She had suffered a brain injury, multiple fractures of the spine and of all extremities as well as a complicated closed thorax and abdominal injury with an intra-abdominal haemmorhage. Shortly afterwards she was operated on and the ruptured spleen, as well as 4 litres of blood contained in the abdominal cavity, were removed. After 17 weeks the patient was discharged from the hospital.

Notwithstanding the successful outcome in this particular case, sufficient cabin space is mandatory to enable immediate and continued intensive therapy. Small helicopters are suitable only for patients suffering from foot and leg injuries.

Because of the type of the injury or its effects, the remaining 18 accidental victims were transferred after having received initial surgical treatment. They included 6 patients for the department of neuro-surgery and 3 patients for the department of dental surgery, in addition to 4 helicopter missions flown to transfer victims suffering from gas gangrene for hyperbaric oxygen therapy. All of these patients had been prepared for transport and were transferred in spacious, heated helicopters with in-flight attendance by doctors and/or medical personnel.

The in-flight emergency equipment consisted of infusion fluids, blood equipment for endo-tracheal intubation and suction and oxygen treatment. In one instance a female patient whose emergency thoracotomy in another hospital had to be interrupted was flown to our hospital in narcosis with anaesthesia apparatus. In our clinic the operation was completed.

Another patient with a serious thorax injury, hemothorax, rupture of the diaphragm and spleen, who received initial treatment in a country hospital, was flown to Düsseldorf over a distance of 160 kilometers with continuous blood transfusion at balanced circulation volume and immediately operated on upon arrival. He left the hospital after 16 days.

Today the transport of emergency patients in exterior cabins cannot be justfied any more. In December last year a severely injured man with Lefort I and II and a lower jaw fracture was transported in a defective exterior cabin resulting in a total undercooling when he arrived at the University Hospital. The rectal temperature was at the critical low of 32°C. A rewarming period of at least 4 hours was necessary before the patient could be operated on.

The other patients for the department of dental surgery were endotracheally intubated or tracheotomised prior to the flights, which were made by large helicopters. Both the neuro-surgical patients and those with brain and spinal cord injuries were air-transported with the attendance of doctors and/or medical personnel. Among the emergency patients flown to the department of medicine we also had hemodialysis.

In Germany the employment of helicopters for emergency evacuation is still relatively rare. It is all the more necessary to illustrate its advantages, possibilities and limitations. As against the well-known advantages of quick and careful transport, there are certain restrictions which one should know:

1. The use of helicopters is dependent on the weather and the time of day;

2. Even though a helicopter cannot land everywhere, it is well able to rescue any victim by use of the cable winch;

3. While piston-driven helicopters need a certain warming-up time, this is no longer necessary for turbine-driven helicopters;

4. The transport trauma caused by vibration and noise may be ignored in emergencies.

From a medical point of view there are certain requirements regarding the types of helicopters:

1. The cabin must be sufficiently large, lined and heatable;

2. The attending staff should consist of an anaethetist and/or medical personnel with shock training;

3. A complete kit must be on board for resuscitation and shock therapy.

Under these premises there are no contra-indications to helicopter evacuation of emergency patients, nor any aeromedical problems caused by low-level flying.

The employment of helicopters is indicated:

1. In emergencies in districts where evacuation by conventional means is either impossible or very difficult;

2. to evacuate emergency patients directly from the scene of accident to the hospital;

3. to transfer such patients to special departments of central hospitals from a country hospital where they have received initial treatment;

4. to transport whole blood and drugs in an emergency;

5. to transport doctors, teams and medical personnel in a catastrophic situation.

The purchasing price as well as the expenses for maintenance and personnel of helicopters are high and not economic for a private company. It is, therefore, suggested that the German military air rescue be extended and based on civilian airports. The emergency ambulance is the standard vehicle for the transport of emergency patients, especially so in urban districts. The utilisation of helicopters should supplement but not replace the emergency ambulance in emergency cases where air evacuation will decisively reduce transporting time or in order to continue intensive therapy.

UNIVERSITY HOSPITALS OF DÜSSELDORF: Air Transports

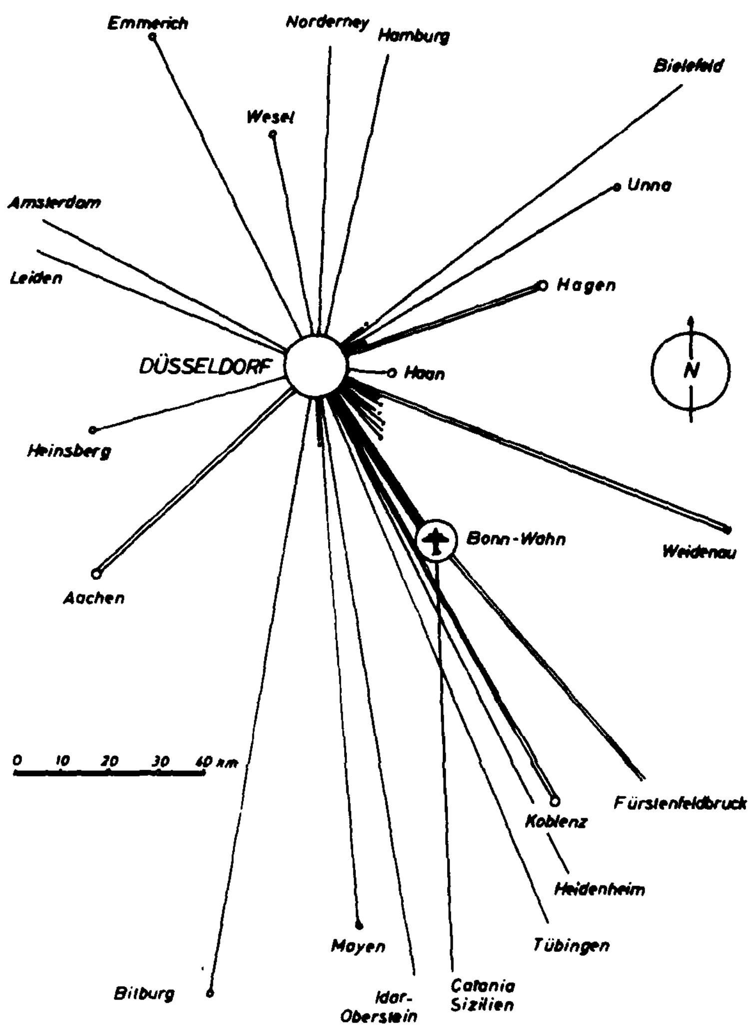

Fig. 1 Map of the air transports in the area of the University Hospitals of Düsseldorf, Germany

UNIVERSITY HOSPITALS OF DÜSSELDORF

Indication		Department of Surgery	Neuro Surg.	Dental Surg.	Medicine	Irradiation	Sum
Emergency Patients directly from Accident Place		7	1				8
Emergency Pat. transfered to Special Treatment	Accident Pat.	7	6	3			16
	No Accid. Pat.	1			7	1	19
Emerg. Transport of Blood		1			1		2
Number of Air Transports		16	7	3	8	1	35

Fig. 2 Transport by helicopter in emergency situations

AEROMEDICAL PROBLEMS IN THE RESCUE OF DOWNED AIRMEN

by

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SUMMARY

This study was undertaken in an attempt to review specific aeromedical problems arising during the rescue of downed airmen under combat conditions and, in particular, to assess the need for new or improved rescue equipment and techniques.

Interviews were conducted with medical personnel and rescue teams recently returned from Southeast Asia. A total of 42 rescues was studied. Information was obtained concerning the rescue and medical support equipment used, rescue techniques employed, type and frequency of survivor injuries, and problems encountered during rescue operations.

Results show the range of injuries sustained by aircrew personnel under combat conditions dictates the need for certain classes of medical support equipment to be carried in rescue vehicles and specific training to be given to helicopter rescue crewmen. The injury classes include: (1) serious loss of blood from lacerations caused by penetrating shell fragments, (2) spinal fractures and severe cervical strains, (3) fractures of one or more extremities, and (4) shock. The equipment carried and the training of rescue crewmen must be appropriate for these injuries.

IN A RECENT SYMPOSIUM held at the Naval Air Development Center, a young Air Force officer who had been rescued following the loss of his plane in Viet Nam gave a description of the condition of a pilot after ejection and safe landing. This officer said that, without fail, the survivor of a combat ejection will be "stiff, scared, sore, tired, and in some degree of shock."

In addition, the survivor may have suffered wounds from anti-aircraft shell fragments or may have been injured during escape from an aircraft likely to be violently out of control. This being the case, we must ask ourselves three questions. First, what rescue equipment is most appropriate for dealing with an individual in this condition? Second, what medical support equipment is required to care for his injuries during the period of transit to a complete medical facility? Third, to what extent may we rely on the survivor to participate actively in the rescue operation?

The Naval Air Systems Command is responsible for the development of airborne rescue vehicles and specific items of equipment used during rescue. The adequacy of this equipment is assessed initially at specific points in the development cycle. Later information concerning the operational adequacy of equipment is gotten, in large measure, from data collected and analyzed by the Naval Safety Center.

There are two points regarding this type of evaluation information which must be considered. First, tests which are conducted during the development of an item of rescue equipment use subjects who are in the best of health and physical condition. This contrasts with the condition of a wounded airman who has just ejected into hostile territory. Second, data concerning the medical aspects of aviation rescues contained at the Naval Safety Center are based almost entirely on accidents occurring during training and operational non-combat flying. This is because there is no requirement for a flight surgeon to complete a Medical Officer's Report when the accident occurs as a result of combat activity. The purpose of this is to lessen the administrative burden on the flight surgeon during such times. However, it removes a valuable source of information concerning the adequacy of combat rescue operations. As a result, this study was undertaken in an attempt to review specific aeromedical problems arising during the rescue of downed airmen under combat conditions and, in particular, to assess the need for new or improved equipment and techniques.

Data for this study were obtained through interviews with medical personnel and rescue teams recently returned from Southeast Asia. Twenty-one flight surgeons and two medical service corps officers were questioned concerning specific rescue events which had occurred during their recent Viet Nam tours. The experience of these individuals was based on service aboard 11 operating carriers and at two Viet Nam shore facilities. In addition, 14 helicopter rescue pilots and crewmen were interviewed concerning rescue techniques and the use of equipment. It is interesting that among this small group of helicopter personnel were two holders of the Navy Cross and two who had been awarded the Silver Star. It is obvious that the life of helicopter rescue crews is not dull and monotonous.

Table 1 presents summary data concerning the rescue narratives which were developed through the interviews. A total of 42 rescues were studied. Of these, the majority were accomplished by helicopters rather than destroyers and occurred at sea during daylight hours.

Table 1

Summary Data Concerning Rescue Cases

Number of rescues studied:	42				
Time period:	March 1966 - July 1968				
Rescue circumstances:					
Helicopter	37	Day	30	Sea	34
Destroyer	5	Night	12	Land	8
Crewman status:					
No injuries	13				
Injured prior to rescue	24				
Died prior to rescue	1				
Injured during rescue	2				
Died during rescue	2				
	42				

Of the 42 crewmen involved, 13 were recovered uninjured. Twenty-four suffered injuries and one died prior to rescue. Two were injured during the rescue operation itself and two, who were apparently uninjured prior to rescue, most unfortunately lost their lives during the rescue process. These last four instances alone provide justification for a detailed examination of current rescue procedures.

RESCUE TECHNIQUES

A neccssary first step in studying the re3cue process is to examine the techniques used by rescue crews.

The Search and Rescue procedures and equipme: t currently being employed in Southeast Asia are undoubtedly the best that have ever been avai.able to carrier-based aircrews. The combat SAR net consists of several ships which maintain station close-in to the shore. On board these ships is the necessary radio communication and direction finding equipment to talk with pilots who are in difficulty and to pin-point their locations. Based on these SAR ships are helicopters and crews specially equipped and trained to locate and rescue downed aircrewmen. Figure 1 shows the UH-2 helicopter, the Seasprite, which was primarily designed for plane guard and search and rescue. This helicopter is the one which is predominantly used at this time for SAR missions. Figure 2 shows the SH-3 helicopter, the Sea King, primarily designed for anti-submarine warfare, but capable of performing the SAR mission. Both helicopters are equipped with rescue hoists, enabling the recovery of downed personnel without having to land.

Combat survivors are rescued from both water and land. To facilitate rescue in both environments a number of rescue devices are used. Table 2 shows the rescue devices in present use. The snap-on connector is used primarily for water pick-ups. It attaches the rescue cable to one of the two riser connector fittings located on the torso harness worn by attack carrier aviators. The rescue sling is used both for water and land pick-ups. The rescue seat and forest penetrator are used for land, or so-called in-country, rescues. Figure 3 shows the latest forest penetrator which is low:.red :hrough trees.

Table 2

Helicopter Rescue Devices
In Use In Southeast Asia

1. Snap-on connector
2. Rescue sling (horse collar)
3. Rescue seat (three pronged seat)
4. Forest penetrator
5. Stokes litter

Combat rescues from th. wat.r have recently undergone a major change. No longer does the helicopter hover over the survivor until the rescue has been completed. The survivor is approached and the helicopter flares, slowing to approximately ten feet of altitude and 10 knots airspeed. The number 2 crewman, designated the "swimmer," jumps from the helicopter at this point. The helicopter departs, makes a circle and returns in about 2 1/2 minutes. During this time the swimmer makes sure of the physical condition of the survivor and prepares him for the hoist maneuver. The helicopter upon returning enters a low hover at 5 feet for approximately 30 seconds while the rescue cable, which has been previously coiled on the floor of the helicopter, is hand cast to the swimmer. The swimmer attaches the snap connector to one of the "D" rings of the survivor and both are hoisted aboard.

This man-in-the-water technique has proven very effective. Rather than rely on the survivor to perform all the pre-hoist actions, the swimmer assesses the situation and acts accordingly. In short, whereas the survivor may be injured and in shock and is in an alien environment, the swimmer is in an environment for which he is well trained.

The swimmer does not wear normal flight clothing. He enters the water wearing a swim suit, face mask, flippers, sheath knife, and a UDT vest (uninflated). Some carry on the vest, inflatable splints (arm and leg) so that a fractured limb can be immobolized for the hoist and helicopter entry. The primary concern of the swimmer is to make sure the survivor is divested of the parachute, and not entangled in any way.

Once onboard the helicopter, the helicopter crewmen perform the appropriate first aid treatment while the survivor is flown to the nearest medical facility, which typically is the SAR ship or an aircraft carrier.

INJURY STATUS OF SURVIVORS

A major reason for this study was to examine the kind and frequency of injuries sustained by aircrewmen prior to and during the rescue operation and then to examine the rescue equipment and medical support equipment in the light of these injuries. It was felt that, inasmuch as this study was restricted to only those instances in which the loss of the aircraft occurred as a direct result of combat activity, the injuries might be somewhat different in kind than those found with operational and training accidents. Table 3 presents a tabulation of the various injury types which

Fig. 1. UH-2 Seasprite Helicopter.

Fig. 2. SH-3 Sea King Helicopter.

Fig. 3. Billy Pugh Jungle Penetrator.

Table 3

Injuries Suffered by Rescued Crewmen

Injury Type	Prior to Rescue	During Rescue
Head		
Concussion	1	
Facial and scalp lacerations	9	1
Facial burns	1	
Upper Extremities		
Lacerations of hands and arms	4	1
Burns of hands	1	
Fracture of arm	1	
Spine		
Compression fracture, cervical	1	
Cervical strain	2	
Compression fracture, thoracic	1	
Compression fracture, lumbar	2	
Back pain	1	
Torso		
Neck lacerations and contusions	1	2
Neck burns	1	
Avulsive injuries of chest	1	
Mid-torso contusions and lacerations	14	1
Lower Extremities		
Lacerations and abrasions of leg and knee	10	
Fracture of leg	4	
Derangement of knee joint	1	
Systemic		
Major shock	4	
Injuries, multiple extreme		1
Drowning		1

were noted. As can be seen, injuries were distributed rather uniformally across the body. There is no evidence of any concentration of injury to a particular body area.

A more informative examination of the injuries suffered by rescued crewmen can be obtained by placing these injuries into a limited number of qualitatively different classes. The result of such a tabulation is shown in Table 4 which shows both the number and percentage of cases falling in seven basic classes. Although the number of cases is much too small to exact any rigorous statistical comparisons, some interesting observations can be made concerning the distribution of injuries shown in Table 4.

The most frequent injury involves lacerations, contusions, and abrasions of various areas of the body. Seventy-two percent of the injured crewmen suffered in this manner. Here we see one rather obvious difference between these injuries and those which would be found with non-combat accidents. Approximately one third of the lacerations were produced directly by penetration of the body by shell fragments or small arms projectiles. In these cases the flow of blood during the rescue process frequently was quite severe, requiring immediate attention by the rescue crewmen. It should also be noted that approximately one out of five of the rescuees had suffered either a compression spinal fracture or a severe spinal strain. This has serious implications for the manner in which the airman is lifted from the water and subsequently transferred from the rescue vehicle. Any bending or serious torsion placed on the spinal regions during this process could seriously aggravate this injury. Fourteen percent of the cases involved a fracture of one or more limbs, indicating a need for readily available splints in the rescue vehicle. Finally, an additional fourteen percent of the cases involved retrieving an individual who was in some state of serious shock. In these cases, the survivor is totally unable to assist in the rescue operation and requires immediate medical attention to prevent further development of the shock condition.

Table 4

Classes of Injury Suffered by Rescued Crewmen (29 Cases)

Class	Number	Percent
Concussion	1	3
Lacerations and contusions	21	72
Spinal fracture/severe strain	6	21
Limb fracture	4	14
Burns	1	3
Shock	4	14
Drowning	1	3

In general, it was found that injuries do predominate in certain basic classes and that the nature of these injuries does have implications both for the type of rescue technique employed and the type of medical support equipment which should be carried in the rescue vehicle.

MEDICAL SUPPORT EQUIPMENT

At this time there exists no standard SAR medical support equipment kit. The type and amount of equipment carried is left to the discretion of the local command. As a result there is wide variation in the medical support items which are carried. The primary duty of SH-3 squadrons is anti-submarine warfare. Therefore they usually carry only very basic items such as blankets, morphine, battle dressings and tourniquets. There are exceptions, of course, where either the plane commander or the command have put together more equipment as they deem necessary. The SAR helicopters, the UH-2's, normally have a more complete set of medical equipment with the addition of splints, oropharyngeal airway, Ace wrappings, scissors or pneumatic cutters, and ammonia ampules.

Many flight surgeons aboard attack carriers have issued additional medical supplies to the attack aircrews. Table 5 shows a list of medical items which flight surgeons report having issued to pilots. The items which have an asterisk are the more common items, ones which almost all flight surgeons reported they have made available to flight crews. This equipment is placed either on or in the flight clothing or in the SV-2 survival vest.

PROBLEMS ENCOUNTERED IN RESCUES

Problems reported by the medical officers and rescue crews interviewed can be classified in three categories: procedures, equipment, and training.

Procedural problems in all cases concern the survivor and are based entirely on comments of the personnel performing rescues. These include the unfamiliarity of the survivor with the rescue equipment, not knowing how to use the rescue sling or the forest penetrator, remaining in the raft (the downwash causes the raft to drift and makes approach by helicopter more difficult), not releasing parachute, and a more subtle comment that pilots are unfamiliar with the null area around the helicopter's antenna which causes a loss of radio communication when directly below the helicopter unless the survival radio antenna is horizontal. Another common complaint is that survivors leave the radios on "beeper" (tone) continually thus jamming the emergency frequency. There is no standard procedure for use of beeper mode and the receive mode.

Table 5

Medical Support Equipment Being Issued to Attack Aircrews

* 1.	Ace wrap
* 2.	Ammonia ampules
* 3.	Battle dressing
4.	Halazone (water purification)
5.	Insect repellent
* 6.	Morphine syrettes
7.	Salt tablets
8.	Tetracycline (infection)
* 9.	Tourniquet (one hand type)
*10.	Water flasks

Equipment problems experienced by survivors involve the usual issues of equipment which fails to operate, items not stored for ready accessibility, and items which either operate improperly or produce additional problems when they are functioning. All comments relate to the well known difficulties of achieving 100 percent reliability in equipment performance under field, and particularly under combat conditions. Solutions to these problems are being achieved as rapidly as feasible.

Training problems concerned both the survivor and the rescue crew. There is a continuing requirement for aviators to achieve an even more comprehensive checkout in the use of personal survival equipment and in current rescue techniques. This pertains especially to the new man-in-the-water procedure.

It was generally concluded that rescue crewmembers require additional training in first aid and emergency medical techniques, additional familiarity with Air Force flight equipment since Air Force personnel frequently are rescued by Navy helicopter crews, and more realistic practice in actual rescue techniques, particularly in the case of crewmen trained primarily in anti-submarine warfare helicopters.

RECOMMENDATIONS

The data of this study, and in particular the comments of those persons interviewed, support three general recommendations. These are:

1. The range of injuries sustained by aircrew personnel under combat conditions dictates the need for certain classes of medical support equipment to be carried in rescue vehicles and specific training to be given to helicopter rescue crewmen. The injury classes include: (1) serious loss of blood from lacerations caused by penetrating shell fragments, (2) spinal fractures and severe cervical strains, (3) fractures of one or more extremities and (4) shock. The equipment carried and the training of crewmen must be appropriate for these injuries.

2. The type and amount of medical support equipment to be carried in helicopters should be standardized. Items should be contained in a manner which permits ready location and identification in daylight or darkness.

3. There is a continuing need to train aviation personnel and rescue crewmen concerning the specific tasks involved in the rescue process and particularly in the use of the rescue equipment.

RECENT ADVANCES AND NEW CONCEPTS IN THE AIR EVACUATION OF PATIENTS IN CARGO TYPE AIRCRAFT

by

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SUMMARY

Recent advances in the development of medical equipment have provided for the capability to safely and comfortably move sick and wounded casualties in multi-mission cargo-type aircraft. The requirement for reduced weight and bulk inherent in the air transport mode has led to many innovations and adaptations in equipment. Equipment has been developed to facilitate the reconfiguration into an air evacuation mode in less than one hour so that casualties may be evacuated by the same aircraft that delivers supplies to forward area airheads. Special medical equipment has been designed for use in the several multi-mission aircraft (C-7, C-123, C-130, C-141) that perform short range (250 Km) tactical missions. On long range aeromedical evacuation missions a special care unit is presently being developed to enable seriously ill patients to be moved over long distances when adequate medical capability is not available at the originating site. Described will be methods for the rapid conversion of cargo aircraft into the aeromedical evacuation role. Also presented will be the contributions of specialized medical equipment to transport casualties in cargo-type aircraft for both the Tactical and Strategic Aeromedical Evacuation (STANAG 3204).

RECENT ADVANCES AND NEW CONCEPTS IN THE AIR EVACUATION OF PATIENTS IN CARGO TYPE AIRCRAFT

DURING FEBRUARY AND March 1968, the Aerospace Medical Division of the Air Force Systems Command assisted an industry team perform a systems analysis of the Aeromedical Evacuation System. A major portion of this study was conducted in Southeast Asia and involves the aeromedical evacuation of casualties in cargo type aircraft. In Vietnam and in off-shore countries (Japan, Philippine Islands, Okinawa, Guam) medical facilities were visited and aeromedical evacuation observation flights accomplished. In July 1968, a study was initiated by the Aerospace Medical Division to determine the effects of early aeromedical evacuation on seriously wounded casualties. The objective of this effort was to describe the battle casualties and their status and problems as related to early movement by air. Discussed in this paper is the movement of casualties in cargo aircraft in the tactical aeromedical evacuation system -- the intra-theater or tactical link from the battle zone to supporting hospitals.

During the war in Vietnam a wealth of experience has been gained. This experience has differed considerably from past wars because:

a. The type of warfare is different.

b. Some instruments of war have changed.

c. Time lapse from injury to definitive care is remarkably reduced as is the time between geographic echelons of treatment.

d. Surgical procedures and techniques have advanced and a host of new medications has been introduced.

The most readily apparent new factor affecting the medical care of battle casualties occurring in the current Southeast Asia conflict is the marked reduction in the time lapse from injury to initial first aid, from first aid to competent resuscitation care, from resuscitation care to first stage surgical care, definitive care and rehabilitation.

After the battlefield pickup and initial surgical treatment, most casualties are further moved to either another hospital in RVN or to a definitive care medical facility in one of the near off-shore countries. Patients are moved from one air base to another in Vietnam and evacuated to off-shore hospitals by the USAF theater aeromedical evacuation system. Theater aeromedical evacuation is the controlled air transportation of the sick and wounded in the combat and communication zone.

BACKGROUND

Tactical air evacuation is the oldest form of moving patients by air. Its history dates to the siege of Paris in 1870 on which occasion 160 patients were successfully evacuated by balloon. In the early developmental years of the airplane it was visualized that patients could be carried by this new means of transportation. Early efforts, however, for this purpose were not regarded as safe or practical. As the performance of the airplane was improved, the feasibility of the airplane "ambulance" became evident to the few military aviation enthusiasts who foresaw the future possibilities of the transportation of casualties by air. During World War I the airplane was used for aeromedical evacuation of casualties only to a very minor extent. At best, the service type of planes were far from satisfactory since a patient was, of necessity, wedged into the narrow cockpi of the open plane. In 1915, during the Serbian Retreat, Captain Dangelzer and Lt Paulhan of the French Air Service evacuated a dozen wounded men a distance of 80 to 200 kilometers using service-type airplanes. In February 1918, at Gerstner Field, Louisiana, USA, Major Nelson E. Driver, MC, and Captain William C. Ocker, Air Service, converted a JN-4 ("Jenny") airplane into an air ambulance. This plane was converted by changing the rear cockpit so that a special type litter with patients could be accommodated. These men are credited with the first aeromedical evacuation of patients in an airplane in the United States and their work aided in demonstrating the practicability of transporting patients by air.

In 1921, Major Epanlard of the French Army organized the first airplane ambulance organization consisting of six airplanes, each adapted for transporting two or three litter patients for use in the Riffian War in Morocco. During these operations in 1922, more than 1,200 patients were aeromedically evacuated. In 1923, nearly 1,000 patients were aeromedically evacuated without accident from forward strips near the Atlas Mountains across desert regions to the hospitals located near established bases far to the rear. This trip required a few hours instead of several days and the airplane definitely proved to be superior to all other forms of transportation.

Aeromedical evacuation in this military operation not only conformed to the principle of early surgical aid for casualties but markedly reduced the problem of transportation. Picque predicted in 1924: "In the future, hours will replace days in calculating the duration of wounded transport." He further illustrated the military and logistic advantages of aeromedical evacuation of casualties. in the following statement: "By rapidly removing the wounded from the fighting zone, the medical aeroplane has, in a remarkable manner, relieved the convoys, economized the fighting troops, and hastened the advance of attacking columns", a statement which appears to have been an accurate presage of future employment of aeromedical evacuation.

THEATER AEROMEDICAL EVACUATION

Theater aeromedical evacuation operates wholly within an overseas theater or combat zone. It is organized, staffed, equipped, and oriented toward combat support. Patient movement is effected within and from combat zones in the specific theater of operations. The Air Force operates two such systems -- one in Europe and one in the Western Pacific area. Since the Korean War until recently these operations had been typified by peacetime evacuation missions of ailing servicemen and their family members. The onset of American involvement in the hostility of Southeast Asia has occasioned smooth transition to the primary combat support mission. Theater aeromedical evacuation utilizes both single purpose and multi-purpose aircraft.

TACTICAL AEROMEDICAL EVACUATION

There are four vital links in the chain of evacuation from the Vietnam battlefields to the hospitals in the United States. These are: forward evacuation in the battle zone; the intratheater or tactical link from the battle zone to the supporting hospital; the strategic link from Southeast Asia to the United States; and, lastly, the final distribution to the hospital within the United States. Battlefield pickup and evacuation is generally accomplished by Army or Marine helicopters that operate during the heat of battle many times under intense enemy fire. In some cases where terrain and conditions permit, the wounded are evacuated directly from combat areas by Air Force fixed-wing aircraft. After the first echelon evacuation, movement between airfields within Vietnam and/or to off-shore hospitals is accomplished through the combat cargo capabilities of the US Air Forces. Normally a 30-day evacuation policy is followed in Vietnam. If it appears that hospitalization will last longer than 30 days the casualty is evacuated from the country. The tactical or intratheater aeromedical evacuation function is based on: (1) the ready availability of many types of combat cargo airlift; (2) on a system which controls the movement and destination of all patients within the theater; (3) on good communication through tactical networks; (4) on the strategic location of in-transit care of casualty staging facilities; and (5) on the presence of trained medical teams who manage and provide care to patients during evacuation. The evacuation of casualties from the combat theater requires a coordinated effort to bring together in timely fashion the medical personnel, the patient, and the means of transportation.

THE PATIENT IN THE AEROMEDICAL EVACUATION SYSTEM

The underlying characteristics of the casualties in Vietnam are those of high energy impact forces on the human body. The application of this energy takes several forms including (1) penetrating or non-penetrating projectiles in various combinations of mass and velocity; (2) extreme temperature exposures, again in various combinations of time and energy exchange, the most common being fire; and (3) concussion, shock and/or bodily impingement on fixed objects. These characteristics initially produce a predominance of surgical/orthopedic cases. Figure 1 shows the distribution of patients evacuated from RVN during February 1968. This time period included the Tet offensive and is representative of intense conventional war casualties. The categories shown are those used by the Armed Services Medical Regulating Office to describe patients in terms of the type of medical specialty.

DISTRIBUTION BY MEDICAL SPECIALTY

Orthopedic Surgery	51%
General Surgery	15%
General Medicine	11%
Neurosurgery	4%
Thoracic Surgery	4%
Hand Surgery	4%
Neuropsychiatric	3%
All Other	8%

Figure 1

Further indication of the type of cases carried in the theater aeromedical evacuation system can be seen in Figure 2 which was derived by analyzing 3,757 selected RVN casualties disposed of by the US Army Command hospitals in Japan during the period August 1967 - January 1968. It must be recognized that the data reflect the coexistence of several case types in the same individual.

Taking those cases that cause real concern in aeromedical evacuation, we find the following percentage distribution when computed against the total number of RVN cases carried.

SELECTED AEROMEDICAL EVACUATION PROBLEM AREAS

Thoracic wounds	7.3%
Maxillo-facial	3.0
Craniotomy	1.75
Liver injury	1.68
G.U. involvement	2.1
Colostomies	1.2
Burns	1.2
Hepatitis	3.8

Figure 3

It is meaningful and practicable to examine the trends in casualty causation associated with hostile action. Figure 4 shows the time between injury and the time the casualty reaches definitive care. Figure 5 shows the death rate for patients received by military hospitals. The movement of casualties from the site of injury to definitive care has become increasingly rapid and the death rate for casualties received has substantially decreased.

Figure 6 shows the site of primary wounds in Vietnam casualties during July, August, and September 19^7. As can be seen from these data, aeromedical evacuation loads are becoming more highly dominated by the surgical/orthopedic patient rather than the general medicine or diseased patient.

THE REQUIREMENTS FOR PATIENT MOVEMENT

The movement of a patient from one medical facility to another involves many basic decisions including (1) the medical aspects of the patient's condition; (2) hospital capacities and capabilities, both originating and destination; (3) the medical prognosis with respect to both the evacuation policy in effect and the patient's remaining tour of duty; and (4) the availability of the

appropriate air evacuation system service to effect the transfer. These, in turn, are dependent upon (5) the availability of an aeromedically configured aircraft, its medical crew, and their special medical equipment. The decision to start the chain of events which eventually result in transfer of a patient from the originating to destination hospital via the air evacuation system is made by the attending physician. There are several options open to the originating physician. In Vietnam, these include transfer to (1) another in-country hospital; (2) transfer to an out-of-country theater hospital; or (3) movement to a hospital in the United States.

There are perhaps three categories of circumstances governing a military situation in which patients must be moved. The first is the ideal one in which there is not only adequate in-country readily available definitive surgical or emergency surgical care, but also the capability to retain the patients for a minimum of two to three weeks. Under these conditions there are few, if any, problems with the air evacuation of patients. The concerns here are the cabin altitude, the low humidity in certain aircraft, and the tension associated with flight.

The second set of circumstances is the situation in which patients can be held for a period between 3 and 10 days. Attempts to restore blood volume, electrolyte balance, bowel function and cardio-reno-pulmonary efficiency are successful to the point that this category of patient meets the minimum physiological requirements for air travel.

In the third set of circumstances, the patient must be moved immediately, i.e., one hour to three days after surgery. This requirement is somewhat contradictory in that a steady influx of fresh casualties requires patients be moved while at the same time the surgical requirements are that the patients should not ideally be moved.

It is through the capabilities of the theater aeromedical evacuation system that these patients are safely moved when the "tactical situation" necessitates evacuation from the combat zone.

DETERMINING PATIENT DESTINATIONS

Following the battlefield pickup of a casualty and initial treatment, there are several policies and factors which determine where a patient is to be hospitalized. Generally speaking, a patient who is to be hospitalized for 60 days or more will be returned to the United States. For fewer than 60 days, he will go to a hospital within the Pacific Command. This is not a firm policy; it is flexible enough to allow a patient to remain at a PACOM hospital up to 120 days if hospital space is available. Very important, and particularly in Vietnam, is the combat situation and plans for future operations. A patient is not held in the theater until the expiration of the period of time which has been established as the evacuation policy. Rather, he is to be evacuated as soon as he has been stabilized to the point that his condition will permit him to safely be moved.

Two communications sequences are accomplished to set the transfer in motion. These two sequence chains involve the request for and granting of destination hospital bed space and aeromedical evacuation system service. Once the attending physician has initiated his request to transfer a patient, a regulating office assigns a destination hospital. Essential information on the patient is furnished to the destination hospital including the date, time, and flight on which the patient will arrive.

CASUALTY STAGING FACILITIES

An integral part of the theater aeromedical evacuation system is the casualty staging facility. The casualty staging facility is primarily a stopping place for patients on their path to the destination hospitals. These in-transit medical facilities are usually located at major air bases in the combat zone. They vary in size from 35 to 250 beds. Often they are incorporated within base hospitals or dispensaries and serve a number of purposes including reception and accumulation of patients for more effective utilization of airlift, re-routing, re-evaluation, triage and stabilization of seriously ill patients, and a haven in the event of prohibitive weather or operational difficulties which might prevent flight. The administrative function of the casualty staging facilities is to insure that all necessary processing is accomplished for each patient including regulation, preparation of orders and manifests, and provision of safe transfer of baggage, valuables, personal documents, and medical records. Medication, intravenous fluids, and special equipment not available on the aircraft are provided to insure adequate care of the patient until he reaches his destination. Transportation to and from the aircraft is provided by the casualty staging facilities. The average amount of time spent by patients in the casualty staging facilities will vary, but it is usually between 6 and 24 hours. In short, the casualty staging facility provides any and all services necessary to give the patient the highest quality of medical and administrative care during the non-flying portion of air evacuation.

The medical staff in a casualty staging facility will vary according to the size of the facility; however, the primary duty of the physicians assigned is the same -- to evaluate medically and surgically each patient and determine whether or not the patient can be aeromedically evacuated without detriment to his well being. Almost all CSF's will have assigned at least two physicians, one with prior surgical training and one who has completed training in aerospace medicine. The primary mission of the nursing service at the casualty staging facility is to provide the continuity of patient care in an environment conducive to the physical, spiritual, and emotional well being of the patients. Casualty staging facilities do not have major operating rooms but possess surgically clean and fully equipped minor surgery, treatment, and dressing facilities. Should patients require major surgery after having entered the CSF, they are returned to the nearest major medical facility. Each CSF has readily available basic laboratory procedures, pharmaceutical supplies, and x-ray facilities. These requirements are met by the supporting dispensary or hospital; however, in some cases the capability exists in the CSF proper where the medical facility is a substantial distance. In the laboratory area the CSF is able to perform CBC, hematocrit, BUN, blood sugars, and urinalysis. If they are located over one hour from a larger laboratory, they have the capability to perform serum sodium, pH, PCO_2 and PO_2.

In addition to the fixed casualty staging facilities, there are mobile units which are self-supporting and have the capability for rapid deployment to airheads in combat areas to provide for the receipt and transit treatment of battle casualties prior to air evacuation. These units can operate from tentage and are located adjacent to or in support of medical clearing companies. The mobile casualty staging units operate at forward air strips where there are no other USAF medical facilities. At these forward air strips only a minimum of processing is accomplished in the interest of speeding the patient to facilities more capable of providing adequate treatment. The mobile casualty staging units operate normally under tentage and have a 25-bed capability.

Unlike the fixed casualty staging facilities, the mobile aeromedical casualty staging units are not attached as an integral element of a parent Air Force medical facility but instead are positioned with the user medical facilities of other armed services. They assist in providing limited supportive medical care and medical and administrative processing to patients awaiting aeromedical evacuation from forward operating airfields capable of accepting fixed-wing aircraft (C-7A, C-123, C-130). These mobile units have very limited staffing and equipment, permitting rapid deployment to and employment at the operational site in a minimum time. Being highly mobile, the unit may be moved as frequently as required to other locations for processing large numbers of casualties into the theater aeromedical evacuation system. Medical, intravenous fluids and special equipment are received from the supportive unit or are requested from aeromedical channels. Transportation to and from the casualty staging unit to the aircraft is provided by any available mode of transportation. In addition to casualty staging, the mobile CSU has a secondary mission to provide emergency in-flight crews using the backhaul capability of any available aircraft required for the immediate movement of a patient whose condition will not permit him to be held for requested aeromedical evacuation mission aircraft from airlift centers. Since patient movement in the forward area often involves the movement of fresh, relatively unstable casualties from crowded facilities, minimum processing of the casualties is necessary for all action is governed by what is best for the patient/casualty.

CARGO AIRCRAFT AND THE AEROMEDICAL EVACUATION MISSION

By virtue of its design, almost any aircraft capable of carrying cargo is potentially adaptable to aeromedical evacuation. Not all of them, particularly the older type transport and the short haul aircraft, are pressurized nor do they all offer the relatively luxurious convenience of the larger piston and jet airplane. With a few exceptions, the cargo aircraft used in aeromedical evacuation provide for vertically suspended, adjustable litter supports, airline type seats for ambulatory patients (which face to the rear as a safety feature), adequate lighting, heating and ventilation, electrical connections for powered equipment such as suction, luggage and supply storage facilities. Oxygen is available in various systems. Ease in loading and deplaning of patients in cargo aircraft is accomplished through special ramps that are available at almost all air bases. Riggings for isolation or modesty curtains are provided. The basic litter supports themselves serve as infusion stands. The requirement for reduced weight and bulk inherent in air transportation has led to many innovations and adaptations in medical equipment. Electrical equipment, for example, has been made compatible with the aircraft electrical supply system and designed to prevent interference with navigation and communication systems. Lightweight aspirators and resuscitator sets are carried on the aircraft. On the medium-sized cargo aircraft, oxygen is carried in small portable, lightweight, low pressure, therapeutic kits with simple continuous flow regulators. They are replenished from the aircraft's central O_2 reservoir. The folding litters with the lightweight aluminum or wooden parallel frames allow for easy portability and security. Most of the items for in-flight patient care are disposable just as their counterparts on a modern hospital ward might be. Plastic bags are used for drainage and colostomies. The flight is equipped with

supplies and dressings and each flight nurse has a kit which is a miniaturized pharmacy. Injectibles come in pre-packaged disposable units and special medication including intravenous fluids are carried as required.

The length of the mission for the in-country (Vietnam) air evacuation will vary but normally averages less than one hour flying time. For the off-shore movements the flying time ranges between 2 to 6 hours. Tactical aeromedical evacuation, being a collateral function of logistical air support operations, has the entire theater airlift resources at its disposal. Depending upon the casualties and the urgency of the movement, cargo aircraft are often diverted from their primary function and reconfigured as an aeromedical evacuation aircraft. All aircraft are subject to diversion or re-routing and they are equipped with litter brackets and other necessary equipment for transporting patients. The aircraft that are used extensively in-country and which are diverted for unscheduled missions in Vietnam are the C-123, C-130, and the C-7 aircraft. Approximately 70% of the total flights in Vietnam are unscheduled. These unscheduled air evacuation missions will usually pick up the medical crews consisting of one flight nurse and two technicians at the originating base. However, they may pick up the medical crew at an enroute base or at the airfield from which the casualties are to be moved.

While the C-130, C-118, and C-141 aircraft are all used to move patients to the off-shore hospitals, the primary mover is the C-141. The C-141 is a high speed, long range, high swept wing aircraft powered by four turbofan engines. Its spacious cargo compartment can be equipped to carry more than 150 troops or up to 80 litters in rows of three and four tiers each. Various configured combinations of litters and seats for ambulatory patients are possible, the usual configuration being 42 litters and 42 seats. The average cruise speed is 420 knots at an average cruising altitude of 33,000 feet.

The largest mover of casualties in-country is the Lockheed C-130 Hercules aircraft. This is a versatile transport that can perform a wide variety of missions. The C-130 can land and take off on short runways and can be used on landing strips such as those found in advance base operations. The C-130 is powered by four turboprop engines and has a normal cruising speed of 311 miles per hour. The C-130 has a pressurized cabin and is capable of accommodating 92 ambulatory patients or 74 litter patients; however, the normal configuration is for 50 litter patients and 28 ambulatory patients. Litters are carried aboard the aircraft through the cargo loading ramp door and are installed in four length-wise rows in the cargo compartment. Stowage provisions for the litter support stanchions are provided in the cargo compartment forward bulkhead.

The C-123 "Provider" aircraft is a very capable performer in Vietnam operating from short unprepared fields to land and evacuate troops and supplies. The high tail assembly and squat landing gear permit tail ramp loading of patients. The C-123 has two piston engines and a speed of 245 mph. It is equipped with standard litter securing devices and has a normal load of 30 litter and 32 ambulatory patients.

The C-7A "Caribou" is a Canadian-built STOL tactical transport formerly designated CV-2B. It was transferred from the US Army to the US Air Force in 1967. It is employed principally in Vietnam where it can land on dirt runways barely 1,000 feet long. It has a range of 240 miles with a full payload and a speed of 182 mph. The normal aeromedical evacuation load is six litters and 15 ambulatory patients. All of the cargo aircraft used for moving patients can be reconfigured from the cargo mode to the aeromedical evacuation mission in less than one hour's time.

CONCLUSION

Aeromedical evacuation in all its various aspects has come of age and is meeting the challenge of today's medical demands in Southeast Asia. The theater aeromedical evacuation system has been able to successfully integrate the capabilities of the combat cargo aircraft of the US Air Force into the casualty evacuation system in Vietnam. The time lapse from injury to first echelon care and between geographic echelons has been remarkably reduced. The rapid, safe movement of casualties to field hospitals and thence the larger medical centers has made prompt specialized care available resulting in the greatest number of wounded being rehabilitated in the shortest and safest manner and substantially increasing changes for full recovery.

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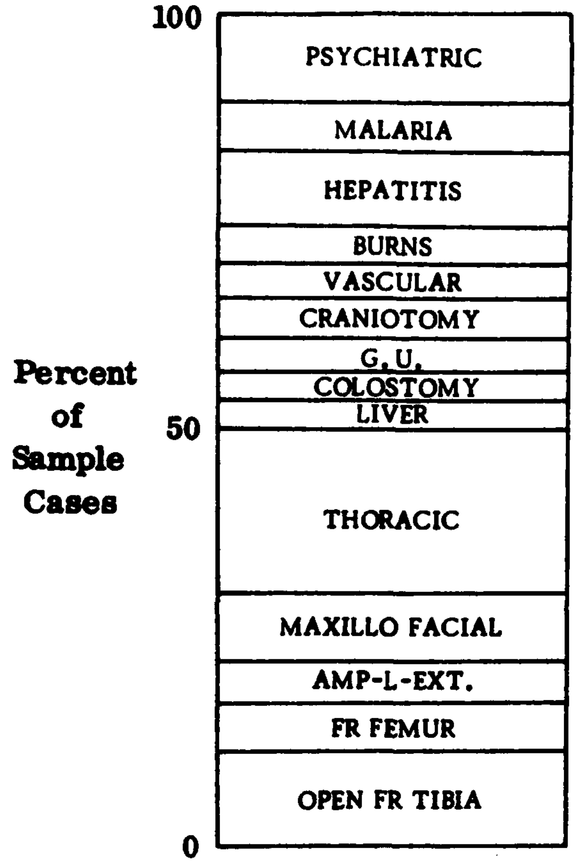

Figure 2 Distribution of Selected Case Types - U.S. Army M.C., Japan, August 1967 - January 1968 (Sample = 3757 Cases)

CASUALTY EVACUATION CHARACTERISTICS

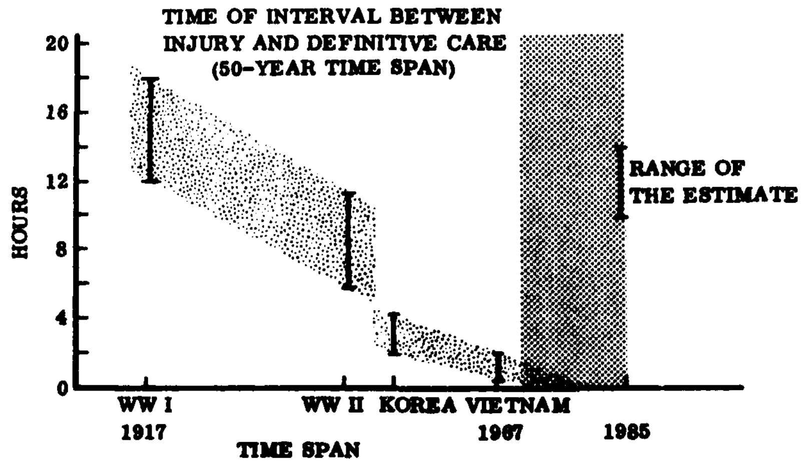

Figure 4

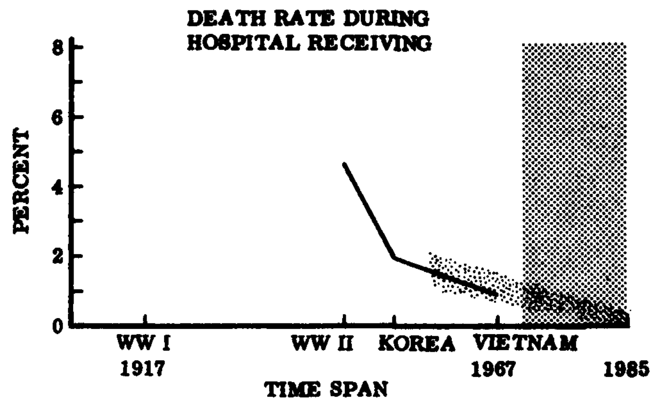

Figure 5

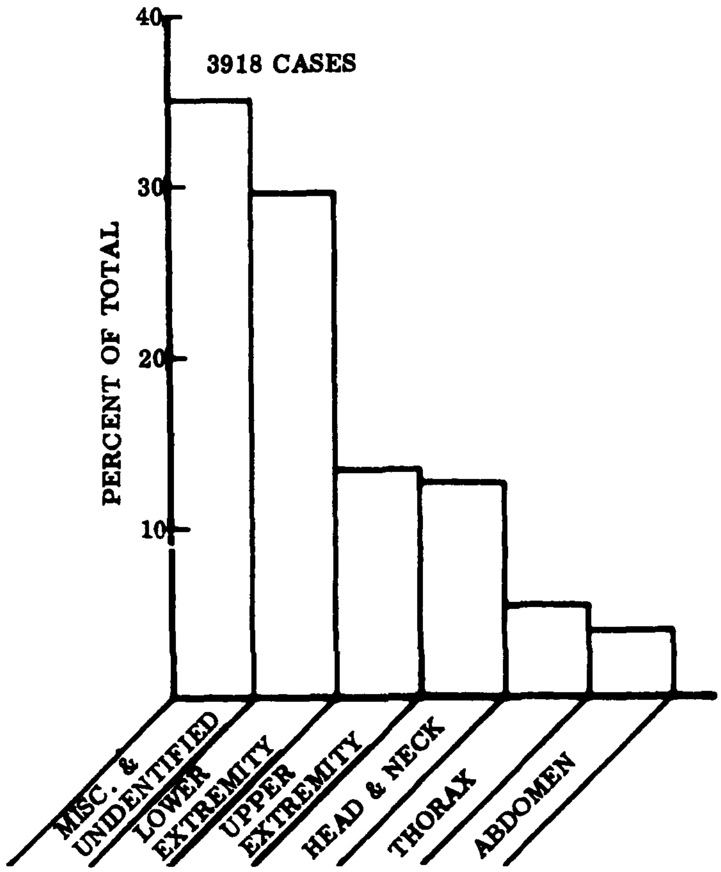

Figure 6 Site of Primary Wounds - Source: Hospital Admissions USARVN

MEDICAL CONSIDERATIONS AFFECTING EARLY AIR EVACUATION OF THE SERIOUSLY ILL PATIENT

by

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MEDICAL CONSIDERATIONS AFFECTING EARLY AIR EVACUATION OF THE SERIOUSLY ILL PATIENT

Lt Colonel Robert C. McIver and Major John K. Murphy

AEROMEDICAL EVACUATION of patients has been utilized for some forty years with varying degrees of success. For the most part, the reason for transportation of the sick and injured has been the nonavailability of definitive medical care or an overload condition in an area where medical care is limited. A great deal of information is available from the Second World War and also the Korean conflict; however, aeromedical evacuation really has been utilized to the maximum only in the Viet Nam crisis. Details of aeromedical evacuation in the Viet Nam conflict have been enumerated in previous reports; however, the medical indications and contra-indications will be dealt with specifically in this paper.

Many patients are moved from one area to another after definitive treatment has been accomplished. These patients are moved primarily to free-up hospital beds in an area of high patient load. There are some instances, however, in which patients must be moved before they have been completely stabilized. The transportation of these patients poses a particular problem in aeromedical evacuation due to the following reasons: (1) the reduced barometric pressure in the aircraft and the possibility of loss of cabin pressure; (2) the reduction in humidity in the cabin atmosphere; (3) the crowded and unsterile surroundings; (4) the high noise level; (5) the alteration of gravitational forces which may be encountered during take-off or landing and also during turbulence which might be encountered during the flights; (6) the limited medical treatment capabilities aboard the aircraft; (7) the inability to transport in the usable fashion different types of sophisticated medical equipment.

One of the most remarkable items that has allowed better survival from battle injury in the Southeast Asia conflict has been the rapidity with which the injured have been transported to areas in which they can receive definitive medical care. This has been primarily the responsibility of the United States Army and has been an outstanding accomplishment. Of course, it is recommended and customary for patients to remain in an area until they are completely stabilized if this is possible in that area. If complete stabilization is not possible, then all attempts must be made to transport the unstable patient with as little additional trauma as possible.

DISCUSSION

The severely injured patient frequently will have multiple injuries. Special reference should be given to cranial injuries, fractures, traumatic injuries of the abdomen and chest, and certainly a primary consideration in all of these patients is to assure oneself that the patients have adequate blood volume, that their dehydration is corrected as well as possible, and that their respiratory activity is as near normal as feasible. If a tracheostomy is in place it should be of a large size and a cuff should be in place if respiratory assistance or controlled respiration is being administered. In certain instances, patients with thoracoabdominal injuries will show evidence of shunting of the blood through the lung. This shunting may be partially or totally corrected by the use of assisted respiration with an increased oxygen tension of the respiratory gas. There are instances in which very high pressures are required in order to ventilate the patient adequately. In these instances volume-cycled respirators usually will afford better

respiration; however, if one uses pressure-cycled respirators with a high enough pressure setting, adequate respiratory activity can be maintained. Pressure-cycled respirators function better at altitude than do volume-cycled respirators, since the number of molecules in a given volume of gas at high altitude may be very low. If the altitude is maintained at six to seven thousand feet, however, there would be no appreciable difference in the function of volume-cycled versus pressure-cycled apparatus.

I would like to make a distinction between respirators and resuscitators. I use the term respirators to indicate those machines which are designed for long-term care in patients who are apnoeic, and I will reserve the term resuscitator to mean an instrument to be used in an emergency when a patient suddenly and unexpectedly ceases breathing. Most respirators are poor resuscitators and vice versa; therefore, in an active aeromedical evacuation system, both respirators and resuscitators must be available. A proper resuscitator should be one that is very simple to operate; one which can be used in any place regardless of power and regardless of propelling gas; one should be able to deliver pressures up to 80 centimeters of water; one must have full control of the inspiratory time phase and the expiratory time phase. The resuscitator should be capable of delivering a tidal volume of one thousand to fifteen hundred cc's and should be capable of delivering gas or oxygen to the individual regardless of the gravitational forces which may be acting.

Since the atmosphere of the aircraft is mostly very dry, some form of humidification should be delivered to those patients who have a tracheostomy in place. There are instruments which, when attached to the tracheostomy tube, will cause condensation of the water vapor in the exhaled air and this water, then, is reinhaled. There are all sorts of humidification devices. Many times one would like to deliver humidified air without increasing the oxygen pressure. Of course, adequate suction must be available at all times.

Some individuals will be transported with chest tubes in place. Many people recommend that a one-way valve be inserted between the patient and the collecting device. This one-way valve will frequently prevent inadvertent pneumothorax from occurring if the tube into the underwater seal happens to become dislodged. In certain instances the one-way valve can be utilized without a collection bag in the event of pure pneumothorax without hemorrhage. In the event that patients have pneumo- or hemothorax, it is much better to transport these patients with the tubes in place rather than removing them before aeromedical evacuation. In many instances a tension pneumothorax can develop due to the reduction in barometric pressure which is assumed during flight. If a chest tube has been removed from a patient, then one should delay aeromedical evacuation of this patient or else reinsert the tube. In all instances, chest X-rays should be taken and reviewed prior to transfer.

Correction as well as possible of any circulating blood volume deficiencies is mandatory since in a person with a normal circulating blood volume and a normal hemoglobin content of blood at ten thousand feet altitude, the arterial pO_2 is in the vicinity of sixty millimeters of mercury, the point at which symptoms of hypoxia become pronounced. If one has a deficiency of the circulating blood volume or has a deficiency of his hemoglobin content, then the amount of oxygen delivered to the tissues will be reduced and symptoms of hypoxia will become even more pronounced. If patients with a deficiency of circulating blood volume must be transferred, then certainly they should be breathing an enriched oxygen atmosphere throughout the flight. Extreme care should be exerted during movement of these patients since frequently just moving them or turning them will cause them to go into a shock condition. In these instances it is much better to have increased the circulating blood volume with some electrolyte solution rather than transporting them with a depleted blood volume.

Transportation of patients with severe burns should, if possible, be delayed until a correction of the vascular deficiencies can be made. The patient should be allowed to stabilize as much as possible. The transportation of a severe burn patient is a very critical procedure and for this reason the United States Army has specific teams which they

send out to retrieve burn patients. These teams pay particular attention to urinary output, functioning airway and coverage of wounds, nasogastric tubes, and functioning intravenous pathway.

Specific attention needs to be given to the gas which is contained in the abdominal cavity, in the thoracic cavity, and in the cerebral cavity since ascent to altitude will cause this gas to expand; therefore, one can anticipate a great deal of difficulty, especially in patients who have thoracic or cranial injuries in which air has been introduced by one means or another. Those patients with ileus frequently tolerate ascent to altitude very poorly and certainly these patients should have functioning tubes to drain the excess fluid and gas from the intestine. In patients with colostomies or ileostomies, ascent to altitude is tolerated well, however, there is usually a marked increase in the amount of flow from the colostomy or ileostomy opening.

Patients can be transported in traction. This is best accomplished by having the traction integral with the patient's body or having the traction integral with the litter or stretcher frame. Since turbulence is not infrequently encountered, the use of weights in traction is not recommended. Spring-type traction devices both for cranial tongs and for extremity traction are preferable.

All plaster casts should be bivalved or at least monovalved before transport, because frequently, especially during long flights, swelling will develop and severe manifestations can result. Marking the cast data on the cast itself is a good means of preserving necessary information. Those casts that are applied to extremities in which vascular grafts have been accomplished deserve special attention during transportation. The casts must be windowed over the graft areas to provide rapid access should bleeding occur. If it is possible, patients who have vascular grafts should not be transferred for a minimum of twenty-one days after surgery. Intravenous fluids must be available in large quantities. Plastic bags of whole blood are the most advantageous since they are easily secured to the stanchions and one does not have to be so concerned about breakage nor infusing of air.

In the event that large numbers of severely injured patients are moved at one time, one should have tracheostomy sets, cut-down sets, catheterization sets, and close-thoracotomy sets available. If tracheostomy sets are not available, one may perform a temporary life-saving procedure by inserting a twelve-gauge needle through the skin and into the trachea. Frequently the obstruction will be only inspiratory; in these instances oxygen can be hooked up to this needle to provide adequate oxygenation even though the patient is not breathing. Of course, the carbon dioxide build-up in this instance will become critical in approximately thirty minutes. However, the procedure can be used in an extreme emergency.

A serious problem in the management of thoracic injury patients has been the wet lung syndrome. This is a difficult syndrome to treat since the etiology and pathophysiology are not understood and the clinical course is not too well defined.

In general, one may state that a severely-injured patient can be transported by air. By far the greatest success will be obtained if the injured patients are stabilized from a cardiovascular, a respiratory, and a renal standpoint before they are transported. There are frequency alterations of the gravitational forces acting on the patient; turbulence is fairly common; the partial pressure of oxygen is mostly reduced; the air is extremely dry; and the aircraft are frequently crowded. The transportation of these individuals, however, can be accomplished satisfactorily if proper guidelines are followed.

RESEARCH AND DEVELOPMENT

IN

SUPPORT OF AEROMEDICAL EVACUATION

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SUMMARY

The primary objectives of the USAF research and development program to improve inflight patient care are presented and certain related efforts summarized. The logic of these efforts as part of an orderly integrated developmental program designed to advance both theory, equipment and practices is touched upon. The continuing requirement to identify, in advance of the need, the kind of research and development that should be undertaken now in order to take advantage of the potential that will be offered by future advanced aircraft systems remains as an underlying theme.

RESEARCH AND DEVELOPMENT IN SUPPORT OF AEROMEDICAL EVACUATION

INTRODUCTION

Approximately three years ago the Surgeon of the United States Air Force Military Airlift Command requested that the USAF School of Aerospace Medicine initiate a research and development program to modernize inflight medical care practices and equipment in the aeromedical evacuation system. The requirement for such an effort can be summarized briefly. The development of military aeromedical evacuation practices and procedures during World War II and Korean conflict time periods was consonant with the operational limitations of the aircraft available at the time. By comparison with present day jet cargo transports, earlier piston engine powered aircraft were slow, small, and vulnerable to unfavorable enroute weather and terrain. Accordingly, the strategic airlift of patients was characterized by fairly long transit times often requiring intermediate overnight stops, modest patient load capability, and weather related uncertainties in flight scheduling. It was necessary that patients selected for such airlift be clinically stabilized, before undertaking such a move. This situation essentially prevailed until the recent introduction of the jet cargo-transport aircraft. These new aircraft, typified by the Lockheed C-141 Starlifter, were fast enough to fly halfway around the world in less than a day with only one or two brief refueling stops. They could carry a large cargo load forward and during the backhaul, as in the case of the C-141, have enough space for 80 litter patients and 13 ambulatory patients. Flying well above the terrain and most local weather and possessing a pressurized and heated cabin, the C-141 could move large numbers of patients for long distances quickly, safely and on schedule, making it possible for a patient to be moved directly from a relatively forward area to a definitive care center in the United States. This capability has been exercised during the present Southeast Asia conflict with substantial numbers of patients (see Fig 1) being moved by aircraft of many types within the theater as well as being returned by C-141 air evacuation aircraft to the United States.

It soon became evident that the patient care system which had been developed in response to an earlier generation of needs and served so well so long required modernization if medical care was to match the operational potential of the new aircraft. Very large patient loads, short overall transit times but long leg times with many patients remaining on litters for as long as 20-25 hours created a new family of requirements. Patients accommodations to simplify loading and unloading procedures, improved access to the patient while in flight, and improved litter comfort were needed. New diagnostic and therapeutic aids were required. Since clinical stabilization could not always be assured, the opportunities for inflight decompensation were increased. These aids had to function in an environmental setting characterized by poor light, noise, vibration and crowding. In addition, these systems had to be logistically acceptable by being light weight, low in volume, simple to operate, safe, reliable, and easy to maintain.

PROGRAM SCOPE

The research and development program designed to improve inflight patient care which was undertaken at the School of Aerospace Medicine gave first priority to the problems of strategic patient airlift, particularly as it related

to the present dual purpose jet cargo transport. Table I shows the main objectives of the program to be improvements in patient accommodations, diagnostic and therapeutic aids and procedures, and the definition of future requirements. Tables II, III, IV, identify individual efforts in support of each of the immediate objectives and thus provide an overall concept of the program's scope. With respect to future requirements, an extensive systems analysis of all major aspects of patient care specifically related to aeromedical evacuation is nearing completion and will be used as a basis for an extrapolation of medical systems for the future that will take advantage of advanced aeronautical systems toward the end that exploratory development can begin now in advance of the need.

DEVELOPMENTAL EFFORTS

The problem of providing a safe, accessable, comfortable, logistically acceptable patient carrying capability received priority attention early in the program. Figure 2, shows a four litter tier using the current system of straps and brackets for litter suspension. The inaccessibility of a patient in the top litter is clearly demonstrated. The development of the simple, lightweight first prototype litter ladder is also shown. This project was undertaken to correct that deficiency. The litter ladder attaches rapidly and securely to top and bottom litter poles. It has a treatment tray to provide a working area, and a safety strap to secure the attendant in the event of turbulence. Although the present system weighs 15.2 kgms (33.5 pounds), minor modifications are expected to reduce that weight by approximately 10 pounds and provide a second generation prototype suitable for operational use.

In Fig 2, each litter is equipped with a new "disposable" litter pad made of a lightweight expanded poly vinyl chloride material. It weighs only 2.45 kgms (5.4 pounds) and occupies .018 meters^3 (.64 ft^3) in the storage mode as compared to the present foam rubber system which weighs 3.3 kgms (7.2 pounds) and occupies a volume of .041 meters^3 1.45 ft^3). Extensive inflight testing has demonstrated a useful life of no less than 26-28 hours with a capability for adequately supporting three average sized men in water survivability testing. Figure 3, shows the litter mattress pad positioned for use.

Figure 4, shows a prototype litter rak system designed to replace the present strap and bracket arrangement. The new method allows litters to be retained in cantilevered type support arms which incorporate a slide out feature similar to a filing cabinet drawer suspension system. This allows patients to be loaded or unloaded in any sequence, and in particular allows the patient to be drawn into the aisle for greater inflight accessibility. Preliminary inflight tests of the prototype were so encouraging that five additional sets, reengineered to optimize weight, shape, reliability and maintainability are now being completed and should be available for test at the time of this presentation.

Efforts to improve patient accommodations include the development of a fast litter tie down device that enables litter patients to be secured to the floor of an aircraft, thus shortening ground time in critical forward areas. A study of new litter designs and specifications to improve performance and comfort while remaining within the present restrictions on overall size is underway. Additional studies include the development of the biomedical design criteria for the C9-A, "Nightingale" single purpose aeromedical evacuation aircraft. The revision of that section of the handbook of instructions for aircraft design (HIAD) which relates to aeromedical evacuation biomedical criteria has been completed. Study to

define the shape and form of a special medical care unit or system suitable for providing definitive emergency treatment and therapeutic support inflight is underway.

Recent surveys of dual purpose aircraft in the aeromedical evacuation mode have shown wide variations in the intensity of lighting at various locations. Levels of illumination as low as 3 (three) foot candles have been recorded between the two lowest litters in a tier. Such levels are insufficient for even simple examinations, inspections, or treatment procedures. Additional light is ordinarily provided by one or more flashlights but has never been a satisfactory solution. The development of a prototype portable, rechargable lamp which clamps to the litter, does not require electrical cords, can be focused and aimed and has several levels of illumination, has been completed. See Figure 5. Initial tests show that the system weighs only 1. 6 kgm (3 1/8 lbs), can operate for 20 hours without recharging and can be recharged on aircraft current. The system requires only minor modification before it becomes ready for operational use.

Because of the background noise in aircraft, the standard stethoscope has been of little or no value as a diagnostic aid. Denied the use of such an instrument, medical attendants have had to acquire vital sign information by observation and palpation. Figure 6, shows an electronic stethoscope which works quite well in jet aircraft such as a C-141 and can be used for auscultation of the heart and Karothoff sounds only. Its performance is severely degraded in piston driven aircraft. In its present configuration it is unacceptably large, bulky and awkward to use. Figure 7, shows a small stethoscope recently designed and built in-house specifically for amplifying the Karothoff sounds only. The device, a frequency translator, alters the low frequency Karothoff sound input. It then amplifies that signal to a frequency spectrum where the ear has its maximum sensitivity. This system has been spectacularly successful in its initial test phase and offers hope that the concept can be extended to heart sounds as well as breath sounds.

The question of providing valid inflight fluid and electrolyte surveillance in severely burned patients has been simplified by the recent development of a prototype lightweight portable laboratory kit, see Figure 8. Its capability includes hematocrit determinations as well as blood pH, and serum sodium, potassium and chloride levels. The complete system weighs only 25 pounds and operated on rechargable nickle cadmium dry cells. The centrifuge is not position sensitive and works equally well lying on its side or even upside down. Glass electrodes are used for the pH sodium and potassium levels and a silver electrode for the chlorides. A suitably trained technician can provide all read-outs in approximately 10 minutes. Testing to date indicates that the results can be expected to be within $\pm$ 2-3% of control ground based reference methods.

As suggested in the introduction, aircraft of different types are used in aeromedical evacuation, particularly in the intra-theater tactical operations. Unlike the C-141, many of these aircraft have no integral therapeutic oxygen systems. Present requirements for therapeutic oxygen are being very satisfactorily met by the use of the standard high pressure oxygen cylinder equipped with a suitable regulator and delivery system. However, the capacity of the cylinder is small and the cylinders are very heavy, making them difficult to move and secure. Figure 9, shows a small, lightweight portable liquid oxygen system which when filled weighs only 50 pounds and provides a total of 12 hours of continuous oxygen at 10 liters/minute after a stand by period of 48 hours. It can be easily secured between litter stanchions and possesses a duel outlet

capability for the simultaneous use by one or two patients. The system can be purged and filled at any flight line having a standard LOX capability because no special servicing equipment is required.

Inflight surveys have repeatedly demonstrated that the relative himidity in the passenger compartment of a pressurized aircraft flying at high altitudes may approach 1-5% shortly after reaching altitude. The general problem of inflight upper airway desiccation and the specific problems associated with airway care in the tracheotimized patient have been consistantly observed. A commercially available compact portable electronic nebulizer-humidifier was minimally modified for inflight use. Inflight patient use show this to be an effective system, soon to be ready for operational use.

The problem of effectively attracting the attention of a flight medical attendant in an aircraft with a high density load configuration is considered urgent. It can only become more acute as advanced aircraft systems of larger size are made available for patient transport. Figure 10, shows a first generation prototype patient-call system powered by dry cells and using a radio frequency signal which does not interfere with the aircraft avionics. The requirements for lightweight simplicity, long useful life, independence from hard wire connectors and positive identification of the patient at the nurses station present problems not yet overcome.

Figure 11, shows a newly designed disposable naso-gastric feeding system that simplified nursing care and logistics. An easily rehydratable powder diet can be stored in the polyethylene bag for up to two years. To use, an outer wrapper seal is opened, the bag is removed and filled with water to a predetermined mark. The fluid contents are then presented to the patient in the usual fashion. The bag is thrown away when empty. Preliminary tests have demonstrated the soundness of the concept.

Maintenance of inflight oral hygiene was not a routine requirement in the earlier days of air evacuation. Such care was offered as part of the overnight hospitalization care given at casualty staging units during scheduled enroute layovers. Since the introduction of a through flight capability, patients are remaining on board the aircraft for the best part of a 24 hour day and the need for interval inflight mouth care has become apparent. Test kits containing a tooth brush, dentrifice, lozenges, lip-ice, disposable plastic tissue cleaner and lemon-glycerine applicators were assembled and then tested in the field. Recommendations for suitable materials and procedures followed and have been operationally implemented.

A portable isolation unit has been developed that protects the patient as well as the environment from bacterial contamination (Fig 12). The unit consists of power pack providing an optional capability to operate independent of an outside electrical current for 4-6 hours. It has an environmental control system that provides an internal temperature varying from 22.2 - 24.4°C (72° - 76°F), even when ambient temperatures approach freezing or go as high as 49°C (120°F), an ultrahigh efficiency filter to remove bacteria from both input and output air, a charcoal filter for deodorization, and a disposable see-through plastic enclosure with glove ports to provide patient access. The entire system as designed and fabricated weighs 120#. It is compatible with the standard litter system and occupies the space normally devoted to only two litters. A second generation prototype incorporating minor changes identified during test is under development and should be ready for test later this year. The latter system which should be suitable for limited operational use will not only facilitate the safe transport of patients in the contagious phase of a communicable disease, but also provide a controlled thermal environment for transporting severely burned patients.

Finally, a series of studies to examine in depth selected problem areas and establish sound guidelines for action have been undertaken. The performance specifications for resuscitators, respirators and aspirators to be used inflight have been agreed upon. Numerous off-the-shelf items of equipment have been examined against these criteria. The criteria for an air transportable hyperbaric oxygenation capability are being studied and the possible requirement for an inflight operational capability being analyzed.

The effect of long distance aeromedical evacuation to alter blood volumes and gases in clinically stable patients with fairly recent traumatic injuries has been investigated in a preliminary inflight study. It is apparent that certain patients show a decrease in arterial oxygen saturation that is disproportionate to the calculated expected ambient values at ambient cabin altitudes. This finding which can be tentatively viewed an "equivalent altitude effect of disease and injury" and needs additional confirmatory studies.

A study of the probable effect of acute exposure to altitudes of 2464 meters (8000 ft) and below, altitudes which are commonly experienced in aeromedical evacuation aircraft cabins, failed to uncover any clinically useful information to suggest that the action of the commonly used therapeutic drugs was altered to an extent that would require either dose changes or substitutions to another substance.

IMPROVE INFLIGHT PATIENT ACCOMMODATIONS

IMPROVE INFLIGHT DIAGNOSTIC AIDS

IMPROVE INFLIGHT THERAPEUTIC AIDS AND PROCEDURES

DEFINE FUTURE REQUIREMENTS

TABLE I.

RESEARCH AND DEVELOPMENT PROGRAM OBJECTIVES TO SUPPORT AEROMEDICAL EVACUATION.

LITTER ACCESS UNIT

DISPOSABLE LITTER PAD

LITTER SUPPORT AND SUSPENSION SYSTEM

FAST LITTER TIE DOWN DEVICE

LITTER DESIGN STUDY

BIOMEDICAL DESIGN CRITERIA FOR C-9A PATIENT STUDY ACCOMMODATIONS

REVISION OF HANDBOOK OF INSTRUCTION FOR AIRCRAFT DESIGN (HIAD) AS IT PERTAINS TO AEROMEDICAL EVACUATION

AIR-BORNE SPECIAL MEDICAL CARE UNIT (STUDY)

TABLE II.

RESEARCH AND DEVELOPMENT TO IMPROVE INFLIGHT PATIENT ACCOMMODATIONS.

PORTABLE LITTER LAMP

ELECTRONIC STETHOSCOPE

BLOOD PRESSURE APPARATUS

PORTABLE LABORATORY KIT

TABLE III.

RESEARCH AND DEVELOPMENT TO IMPROVE INFLIGHT DIAGNOSTIC AIDS.

PORTABLE LIQUID OXYGEN SYSTEM

ELECTRONIC NEBULIZER - HUMIDIFIER

PATIENT - NURSE CALL SYSTEM

NASO-GASTRIC TUBE FEEDING SYSTEM

ORAL HYGIENE MATERIALS

PORTABLE, BACTERIAL ISOLATION UNIT

EVALUATION OF RESUSCITATION AND RESPIRATORS (STUDY)

EVALUATION OF ASPIRATORS (STUDY)

PORTABLE HYPERBARIC OXYGENATION CAPABILITY (STUDY)

INFLIGHT ALTERATIONS OF BLOOD GASES AND VOLUMES IN WOUNDED PATIENTS (STUDY)

LONG DURATION FLIGHTS AND THE EFFECTS OF DRUG ACTION (STUDY)

TABLE IV.

RESEARCH AND DEVELOPMENT TO IMPROVE INFLIGHT THERAPEUTIC AIDS AND PROCEDURES.

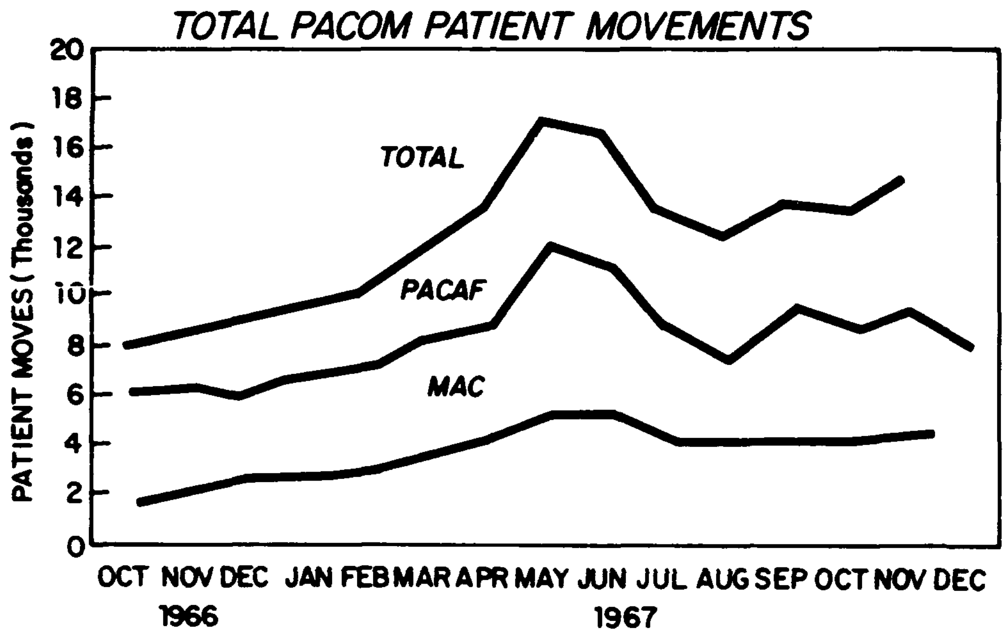

Figure 1 - Total PACOM Aeromedical Evacuation Patient Movements from Oct 1966 - Dec 1967. PACAF movements are primarily intratheater and MAC figures represent intertheater patient movements.

Figure 2 - Portable Litter Access Unit

Figure 3 - Disposable Litter Mattress

Figure 4 - Litter Suppoɪt and Suspension System

Figure 5 - Portable Litter Lamp

Figure 6 - Electronic Stethoscope

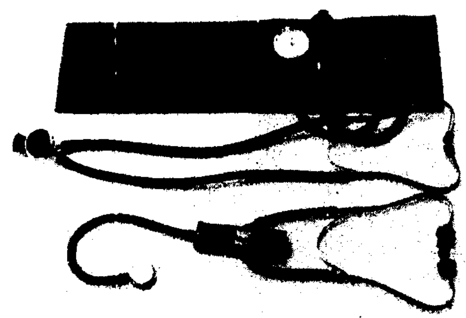

Figure 7 - Blood Pressure Monitoring Device

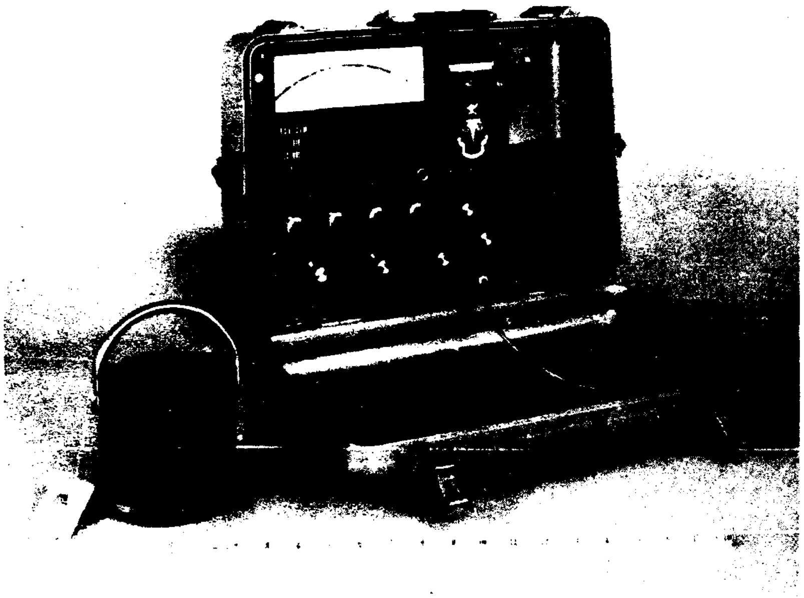

Figure 8 - Aeromedical Evacuation Laboratory Kit

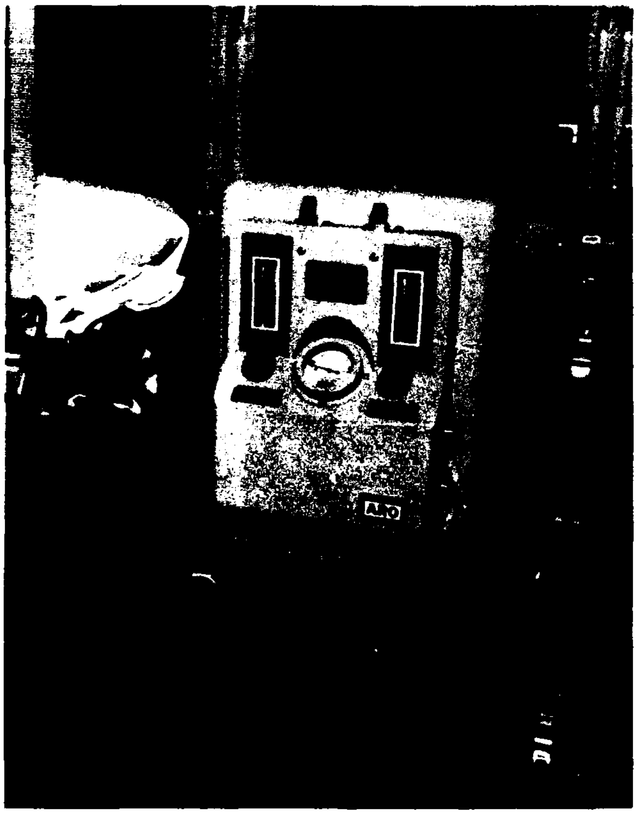

Figure 9 - Portable Liquid Oxygen System

Figure 10 - Patient-Nurse Call (Alarm) System

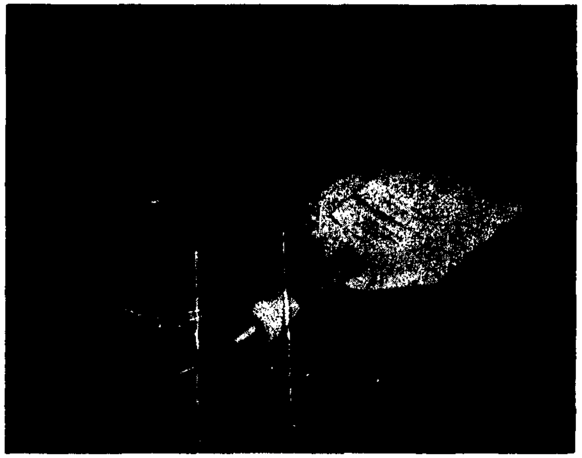

Figure 11 - Improved Nasogastric Feeding System

Figure 12 - Bacterial Isolation Unit

A LIGHTWEIGHT PLASTIC LITTER

by

CAPTAIN I.C. PERRY MB BS D AV MED, RAMC.

SUMMARY

This paper presents an idea about a piece of equipment and some progress to formulating the idea as it was first suggested last year in Paris.

The arguments for such a piece of equipment are put forward and some arguments against. The idea of a simple moulded plastic litter to replace conventional poles with something strong between them is not easy to accept after so many years getting the general stretcher perfected. The stretcher is however undesired by the aircraft designer as it is too long, cumbersome, heavy and always presents problems. It is suggested therefore the time is at hand for a change.

At the end of the Helicopter Symposium held in Paris last year it was suggested that a new form of stretcher was required. Such a stretcher needed to be light in weight, robust, capable of being x-rayed through, cheap to produce and able to fulfil many roles. My interest in this has developed due to the fact that in Army Aviation we are having difficulty in fitting the old well-tried system of two poles with something in between into our new range of aircraft. As was said last year, surely the time has now come to have a new and more suitable piece of equipment for our new aircraft, rather than to build and fit these new aircraft around ancient equipment.

After a lot of practical experience I consider the version of the Stokes litter used in the British Army to be an excellent piece of equipment. It is extremely light, weighing x pounds or y kilos. However, it is perhaps longer than is needed to cater for the height of the 95 percentile man and, being made of metal, it is radio-opaque. Although strong, it is not as robust as one would like. In British Army aircraft it is carried externally, there being no aircraft capable of carrying it internally.

A litter of similar shape although of somewhat different dimensions and form and made of a tougher material which is lighter in weight, and which could be x-rayed through would be nearer to our needs. Such a litter could be carried on racks inside the aircraft and by virtue of its low weight and its shape would be capable of being nested in great numbers so that large quantities of them could be stored and transported in very small volume. A casualty could be put into such a litter on the battle field and would not need to be removed from it until he was ready for his hospital bed, the litter acting if needed as stretcher, plaster cast, x-ray couch and operating table. If made in a basket form it could be dragged, floated (if necessarily after the addition of a collar), lashed and winched more satisfactorily than a conventional stretcher. If suitable projections were provided on the under side, it could also be made to fit all the fittings and floor runners now in use thereby replacing the conventional stretcher in all forms of transport.

Change is generally frowned upon if it means disturbing a peaceful existence. Changes in any form of equipment also mean at least some cost in replacing stock piles of the existing items. To change the conventional stretcher which has been satisfactory for 50 or more years could not be embarked on lightly.

In aircraft design, space is very limited. For example, one new small rotary wing aircraft has an oblong cabin and can seat ten men. In the casualty evacuation role however, it will only take three conventional stretchers fitted diagonally across the cabin. This makes loading extremely difficult which becomes of even greater importance when untrained ground troops have to be used for the task as would be the case under combat conditions. Very valuable space for other casualties, men or stores which the aircraft is capable of lifting cannot be made use of. The economic advantages of making full use of this lift capability by the use of a new form of stretcher would in large measure repay most of the costs of replacing our conventional stretchers.

In all the stretchers with which I have experimented the main problem has been the projection of the handles. All stretchers, no matter from which organization or country, have shown this same defect. Something is required, therefore, without handles. As the Stokes litter is too long and is radio-opaque, these defects, too, must be overcome.

A smaller, plastic litter has been developed and a prototype is shown here. Basically, it is extremely simple, being nothing more than a plastic shell which is strong and robust enough to fulfil all the roles already mentioned. The prototype is crude and no more than a space model. Being made of glass reinforced plastic, which is a convenient laboratory construction for such prototypes, it is very heavy and has been used to define only the necessary shape structure and size. Investigation has already shown that the use of suitable modern materials and methods of manufacture could be used which would ensure very light weight indeed together with adequate strength and rigidity at very low cost. These preliminary investigations suggest that with production of an adequate quantity the unit cost would be low enough to enable them to be regarded as disposable items.

Such an approach has a few major faults. As in most other developments, the advantages of the incorporation of some features has meant disadvantages by the elimination of others. Perhaps the main obvious disadvantage is that if you are more than 6 ft 3 in. or z cm. tall your feet or head must hang over the end. However, this is already so in the conventional stretcher. It has already been commented that such a device cannot be used with a Thomas splint which is a device with a leg loop and full length metal stirrup used for treating fractures of the femur. This may be so, but neither can it be used with the Stokes litter we now use. This need could be catered for by fixing the leg to the litter and even by

applying traction from the bottom slats. If necessary, the leg could even be plastered into the litter.

Another fault is that such a litter would be so light that rotor downwash would blow it away very easily. Rotor downwash would also blow the Stokes litter, the conventional stretcher or virtually anything else away. In the British army we train men to keep such items away from the area of the downwash and the only time that such a litter should be in the area should be when it contains a patient and is being carried to the aircraft. Unlike the conventional stretcher, it can be carried from any of its four sides by any number of men.

Such a concept has been rejected by some on the grounds that it has taken so long to reach agreement on the present day systems that it would be unwise to offer an alternative now. However, there is some evidence that aircraft designers would welcome this alternative because of its space and weight advantages. Most of you must have handled a stretcher at one time or another. I would like to know your views and would welcome your criticisms or suggestions.

PANEL CHAIRMAN'S CONCLUDING REMARKS

"Ladies and Gentlemen,

All good things must come to an end and it is with regret that I must bring this 25th meeting to a close.

I wish to extend my thanks and yours to the United Kingdom for permitting us to have our meeting in London, and in particular to the National Delegate, Mr Handel Davies, who extended the invitation.

I'm sure that you would also like me to thank the distinguished speakers who addressed us at our opening ceremony; the Chief of the Air Staff, Air Marshal Sir John Grandy; the National Delegate, Mr Philip Hufton; the Director General of Medical Services of the Royal Air Force, Sir George Gunn; and the Director of AGARD, Mr Franklin Ross.

I think that we have been fortunate to have our meeting in such pleasant rooms and I wish to record our appreciation to the Council of the Zoological Society of London. In this context, our thanks also to Mr Fish, the librarian and the housekeeper and projectionist for all the practical help they have been in permitting the meeting to proceed so smoothly. I would also like to add a personal word of thanks to our AGARD staff, namely Colonel Grunhofer and our Secretary, Miss Ann McStravick; also to Mr Smith of the Ministry of Technology who handled many of the administrative arrangements and the local programme chairman Group Captain Dobie and his staff for their help in trying to make our meeting enjoyable.

I am sure that we all thank our eloquent speakers and our Session Chairman for the interesting and useful presentations and discussions we have had this week. I believe that this type of presentation makes a most useful contribution to NATO effectiveness. Our thanks also to our interpreters, without whose skill and endurance this meeting would have lacked very much.

I am sure that you would also wish me to mention our most enjoyable social programme. In particular the kindness of the National Delegate Mr Philip Hufton for receiving us and entertaining us to cocktails. I wish also to record our thanks to Sir James Martin of the Martin Baker Aircraft Company for so generously entertaining us to cocktails. It was a great personal pleasure for me to meet Sir James Martin again and I shall be writing to him on your behalf. I hope also the Ladies enjoyed their programme and on their behalf I thank Lord Redmayne of Harrods for the interesting visit, and Lord Milner who arranged the conducted tour of the Houses of Parliament. A special word of thanks also to Mrs Whiteside, who looked after the ladies for us. We were so pleased that some of the delegates brought their wives with them to this meeting.

I also would like to thank Air Commodore Roxburgh and Group Captain Ferguson who is the Commanding Officer of the Institute of Aviation Medicine and his staff for the interesting visit which has been arranged at Farnborough for tomorrow. Also to Group Captain Whiteside who handled many of the details for the visit.

If I have missed anyone, I hope that they will forgive me. We have met so many people and they have done much to make our stay a pleasant one. With regret, Ladies and Gentlemen, I now bring this meeting to a close and I bid you farewell and a safe journey, in the hope that you have found our 25th Meeting as useful and interesting as I have."

E. A. LAUSCHNER,
Professor, Dr. med.,
Brigadier General, GAF, MC,
CHAIRMAN
AEROSPACE MEDICAL PANEL

TECHNICAL SUMMARY

The 25th meeting of the AGARD Aerospace Medical Panel was held at the Meeting Rooms of the Zoological Society of London from the 15th-17th October 1968 and was followed by a visit to the Royal Air Force Institute of Aviation Medicine at Farnborough, Hampshire, on Friday 18th October 1968.

Eighty-six delegates attended the meeting representing twelve NATO nations and the NATO Headquarters.

The meeting was opened by Professor Doctor E. A. Lauschner, Brigadier General, GAF, MC, the Chairman of the Aerospace Medical Panel. Professor Lauschner welcomed the delegates and introduced in turn the four distinguished guest speakers namely, Air Chief Marshal Sir John Grandy, RAF, Chief of the Air Staff; Mr Philip Hufton, United Kingdom national delegate to AGARD; Air Marshal Sir George Gunn, RAF, Director General of Medical Services; and Mr Franklin Ross, Director of AGARD.

In his opening address, the Chief of Air Staff stressed the importance of the NATO alliance and the very large contribution that learned bodies such as the Aerospace Medical Panel made toward the cohesion of NATO. Air Marshal Sir John Grandy also referred to the continuing importance of man in the operational defence role in aviation and the vital contribution of the Panel in this field. Mr Philip Hufton, a Deputy Director of the Royal Aircraft Establishment, Farnborough, also stressed the continuing need to obtain a good match between man and machine, as complex electronic and avionic systems were developed to improve crews skills. Mr Hufton also referred to the valuable contribution made by the panel in giving advice to the various member nations both in respect of training and general problems in the field of aviation medicine. Air Marshal Sir George Gunn expressed his pleasure at the references by the previous speakers to the importance of the human factor in aerospace systems and of the need for medical representation in the multi-discipline teams necessary both for the promotion of research and for the interpretation of the results. In this context, he also referred to the unique advantage to ASMP of many of it's members being Flight Surgeons or Flight Medical Officers, having close association with the problems of operational flying. Mr Franklin Ross, the Director of AGARD, considered that the programme topics were a very strong indication of the extent to which aviation medicine could contribute to the operational aspects of NATO's mission; that the programme was well balanced covering several areas of great operational, military and medical interest. Mr Ross also referred members to the successful cooperation with the Structures and Materials panel, which was to contribute to the section on body armour at this meeting.

Professor Lauschner thanked the guest speakers for their presence and the stimulating and generous remarks that they had made about the Aerospace Medical Panel. He also recorded the Panel's appreciation to the United Kingdom for the invitation to hold this year's meeting in London. Finally, the Chairman extended a warm personal greeting to all the guest speakers, panel members and delegates in the sincere hope that the meeting would be interesting, stimulating and useful, not only to the medical branches of the NATO forces, but also to the effectiveness of the NATO operational Air Forces.

The first session, on Pattern Recognition was chaired by Colonel Professor A. Scano, IAF, Vice-Chairman of ASMP. The three papers in this session were not only very important individually, but also of the greatest interest when considered together. The experiments carried out by Dr. Davies showed that, in particular conditions of target size and background contrast, there was a close relationship between the theory of visual search and the acquisition of targets. In search conditions, namely, with successive glimpses of short duration and in dynamic conditions corresponding to the practical aspect of air to ground visual search this also held good. He also showed that when the target size varied, the probability of recognition also changed in proportion. This confirmation of theoretical data in the sphere of target acquisition, had been carried out both by means of simulators and in actual flight conditions. The work by Professor Howarth and Dr. Bloomfield in their field of visual search had made a valuable contribution by examining various factors concerning both target specification and the camouflage effect of complex

backgrounds. This was the beginning of a continuing effort by these workers to devise ways of predicting both the range and the latency of detection of real targets from a physical specification of the target and its background. Apart from the significance of the outcome of this particular research, the simple search situation that had been developed for this work was most interesting and seemed likely to have wide application in that field generally. The device was seen to be of value, not only in assessing the various relationships between target and non-target sizes, number and duration of fixations, but also as a means of demonstrating the importance of training and, therefore, search time as a function of the many different parameters.

The paper by Scano, Meineri, Caporale and Longhi represented a contribution to the knowledge of visual perception phenomena in various gravitational fields. The rapidity, accuracy of perception and localisation of the image, would be ascertained by means of a magnetic tape recording of subject responses under different conditions.

The work described in these papers was, in many instances, in its early stages in many cases and the laboratory data would require confirmation under multi-stress, in-flight conditions. These early results were most interesting, however, and were likely to make a valuable contribution to this highly important operational field of target acquisition. The outcome of such work, with particular reference to the high speed low level flight condition could be of great significance to the NATO operational commander.

The second session of the day, chaired by Group Captain T. C. D. Whiteside, RAF, also consisted of three papers on the general topic of pattern recognition from the visual point of view. In the first paper by Wolbarsht and Wagner, the fundamental neurophysiology of the retinal organisation in pattern recognition was discussed. This presented an interesting concept of the role of the ganglion cells in coding and auto-correlating the information from the retinal cells, for example, in colour perception. This paper is not published in these proceedings. The second paper, by Hopkin, reviewed the discrepancies and weaknesses of current and, in certain cases, proposed maps and charts. The author drew attention to the need for a complete redesign of the described material based on the different requirements of the airborne task. As an example of this, in low level flight, geodetic and man-made features were recognised by their elevation rather than the plan view that was usually presented on maps. In the final paper, Professor Mercier described the findings of a fairly simple questionnaire on the subject of the illumination of aeronautical charts. The comparison of Fighter, Military Transport and Civil Aviators' preferences showed that in cruise conditions most preferred white illumination, but that in the landing, take-off and climbing phases of flight, red light was usually preferred. The questionnaires also showed that younger pilots had more preference for red lighting.

These three papers ranged from the theoretical to the applied. The first paper could be regarded as a scientific briefing for aeromedical specialists. The second paper emphasised the fact that present day maps and charts were not good enough for high performance aircraft. They tended to be too complex, read too slowly and failed to present the information required by the aviator during specific flight profiles, such as the high speed low level situation. It was to be hoped that this formal statement of these limitations would go some way toward encouraging improvements in this important subject. The user opinions expressed in the questionnaires described in the third paper lend support to the conclusions of the Symposium on Aircraft Instrument and Cockpit Lighting by Red or White Light, which were published recently, (Conference Proceedings No 26).

The final session of the day was chaired by Professor Mercier and consisted of two presentations. The first, by Dr. Robert Camp, discussed the philosophies of voice communication systems design, and the second paper, presented by Dr. Miro, was a late addition to the programme and described the action of a magnetic field of 42,000 gauss on the growth of Bacillus coli. Dr. Camp played various recorded tapes in order to demonstrate the importance of improvements in voice communication systems between aircraft and the ground. The first tape was a communication between a private aircraft in difficulties and a control tower; the second was a recording of a military aircraft communicating with its control post and the final tape was recorded in a Chinook helicopter. In all three cases the sound was of very poor quality, resulting in difficulties of comprehension.

The author then demonstrated tapes from a new modified communication system in which the reproduction and subsequent speech comprehension were materially improved. The author suggested that the philosophy of systems design which had evolved since World War II was largely responsible for the present day low efficiency systems. In particular, the author felt that the popular assumptions held by design engineers about distortion, band width conservation and speech intelligibility criteria would explain some of the reasons for the failure to develop a successful voice communication system. The final paper of the day, present by Dr. Miro, was intended to show the influence of magnetic fields of strong intensity on the organisms of Bacillus coli and, by extrapolation, on man himself. The authors have shown that the growth of the bacteria was not affected when the magnetic field was continuous. On the other hand a sharp variation in the field produced a sharp increase in the growth rate which returned to normal in the absence of any further variation in the magnetic field. In the discussion which followed, the author pointed out that, in this context, the effect of a magnetic field was comparable to the effect of an electrical field.

This completed the first day of the conference, and the session on pattern recognition. The majority of the papers were concerned with the visual aspect of pattern recognition and ranged widely from the theoretical to the practical situation in the cockpit of contemporary aircraft. The interest which the various papers promoted was shown by the discussions that followed; the further need for both basic and applied work in this field was rightly emphasised by the various speakers.

The second day of the conference saw the beginning of the section on body armour and aircrew equipment assemblies. The Chairman for the first session was Colonel R. H. Shamburek, MC, USA. This session consisted of five papers on body armour. The presentations by Dr. Sullivan, USA, and Captain Leomand, FAF, were given on behalf of the Structures and Materials Panel of AGARD. Dr. Sullivan reviewed the recent history of body armour in the United States and went on to discuss current construction, using plastic and ceramic materials, particularly boron, silicon and aluminium carbide. The author pointed out the change in the distribution of wounds that had resulted from the use of body armour, with a reduction of chest, back and abdominal injuries. He also stressed that the increase in combat effectiveness resulting from confidence in body armour, and the associated improvement in morale, were highly important justifications for the use of body armour which were probably often overlooked. Lieutenant-Colonel Gregory, USA, presented various observations on body armour that had been derived from aircraft accident reports. He pointed out the outstanding problem areas, e.g. excessive weight, inadequate ventilation, lack of buoyancy, incompatability of body armour with other items of personal equipment and the difficulties of removing the equipment. Mr Baker described ceramic based body armour consisting of small overlapping tiles of ceramic, which could be produced in almost any size or shape. This construction had the particularly interesting property of being able to withstand successive strikes. He demonstrated a new vest for aircrew that incorporated this type of protective armour in a quick release attachment. The vest also had a unique means of weight bearing in which most of the weight of the armour was taken on the waistband. Mr Baker's paper was not available for publishing in these proceedings. Major Murphy reviewed the development and successful operational use of body armour during low altitude flight missions in Vietnam. Specific mission requirements and the requirements of aircrew compared with those of ground crew with respect to body armour were also discussed. Captain Leomand described body armour both in vest form and pullover form, that utilised overlapping plastic laminated tiles. He was of the opinion that the current weight of most items of body armour was still excessive and recommended that an optimum weight of two kilograms should be aimed at.

The survey of body armour was both interesting and comprehensive. The saving of life and reduction of wounds that had been achieved by the use of body armour was most encouraging. The point which was made with regard to the value of body armour in raising morale and thereby combat effectiveness, was a point of view which should be of interest to the operational commander. It was also clear, however, that the development engineer was still faced with many difficult problems. These were mainly concerned with the reduction of weight of body armour and improving its compatability with the wearer's work space, task, and other personal flying equipment before body armour

could be used widely without functional detriment. In discussion, the question of armouring parts of the aircraft was considered; it was pointed out that the weight penalty was considerable and on balance the emphasis had therefore shifted towards personal protection. On the question of weight of personal armour, one of the significant factors that had emerged was the rapid increase of cost as the weight was reduced.

The next session consisted of papers on aircrew equipment assemblies and was chaired by Group Captain T. G. Dobie, RAF. There were four speakers in this interesting session which covered certain fundamental and applied aspects of aircrew protection. The first speaker discussed the principles of safety harness design and presented a method of harness assessment. This presentation highlighted the valuable contribution that the aeromedical doctor can make in an area that had previously been the exclusive province of the engineer. Although many of the test measurements were stress tests, throughout a gradually increasing range of accelerations in different planes, the results also took into account, harness comfort, ease of use throughout a representative range of body sizes, as well as harness restraint. The second paper reviewed the problem of providing thermal protection to aircrew, both in the routine flying and emergency situations. The speaker described a programme of physiological assessment of five different USN aircrew protective suit systems under different environmental conditions. He highlighted the great problems presented by such a requirement and suggested that no single suit could provide a satisfactory solution to both the routine and emergency situations. The value of a combined suit, life-raft assembly to cover the wide thermal spectrum was stressed. The third speaker reviewed the work that had been carried out in the field of water-cooled suits. In doing so, he confined his remarks principally to the programme in the UK. The author, although accepting the feasibility of this method of body cooling, expressed some doubts as to whether the user could control the suit function by personal choice rather than by means of an automatic temperature regulating mechanism. The practical problems of suit mechanisms were not covered in the presentation. Subsequent discussion, however, highlighted the difficulties associated with the accurate measurement of body temperature. The final paper in this session consisted of a well presented survey of flash blindness protection systems by Dr. Gloria Chisum, USA. The speaker concluded that the use of photochromic techniques offered the most likely solution to this problem, although the ideal solution was not yet available because of apparent technological difficulties. At present, photochromic goggles had the great disadvantage that they reduced light transmission by some 50% in routine use. On the credit side, however, they were capable of speedy onset of operation, reversibility and could be used repeatedly. The importance of reaching a satisfactory outcome to this problem was stressed, with particular reference to the low level flight profile.

This was yet another interesting session covering examples of both basic and applied aeromedical problems. The first paper was an interesting example of the multi-disciplinary approach to the solution of practical problems and the value of medical specialists in the combined research team. Other papers highlighted practical difficulties in the area of aircrew equipment assemblies and demonstrated, only too clearly, certain practical problems of low level high speed flight, both in the realm of thermal stress and the additional hazards of flash blindness in the tactical situation.

The session on Current Space Medical Problems was chaired by Colonel R. S. Malone, Chief of the Medical Research Group, Headquarters USAF. It began with two papers on cardiovascular studies, continued with one paper related to a new index of respiratory stress, and closed with two papers on the problems associated with high oxygen tensions. In the opening paper, Lieutenant Colonel Lancaster, USAF, MC, reported the results of protracted bed rest studies. He showed that stroke volume, plasma volume, red cell mass and skeletal muscle mass were significantly decreased by 30 days of bed rest. He further pointed out that a relatively long time was required before these return to normal after the reinstatement of ambulation. Major Triebwasser, USAF, MC, provided further data on the metabolic and haematologic aspects of hypodynamics. These showed that during protracted bed rest studies, metabolic requirements decreased by 30%, and that adipose tissue replaced the loss of muscle mass described by the previous speaker. The nitrogen sulphur and

potassium balances became negative and red cell production was decreased. In the third paper of this session, Squadron Leader Denison, RAF, described a new methodology for the measurement of mixed venous blood gas tensions by a rebreathing technique. He also described how the gas tensions in mixed venous blood provided a particularly useful index of cardio-respiratory stress. Describing the results of several hundred observations, the author showed that estimates of alveolar ventilation, cardiac output, residual volume and alveolar mixing were by-products of the methods employed. Dr. Kydd presented a paper on the effects of prolonged exposure to high oxygen tension. Rats were exposed to 100% oxygen at two-thirds of an atmosphere for 30 to 47 days. Hypertrophic and, in some cases, hyperplastic changes were found in the pulmonary vasculature; pulmonary hypertension and systemic hypotension were also observed. In the final paper, Captain Carter, USAF, discussed methods whereby chamber safety could be enhanced when using oxygen enriched atmospheres. He discussed the characteristics of fire extinguishing systems that had been developed for use in this potentially hazardous situation.

This session provided interesting papers on different aspects of current space medical problems, both practical and theoretical. The papers were received with great interest, not only because of the quality of the work, but perhaps because they had many, often practical, applications that were not specifically related to the problems of space.

The first part of the session on Aeromedical Evacuation was chaired by Brigadier General J. J. Varela of the Portuguese Air Force. It began with a paper by Wing Commander Atkinson, RAF, who described the arrangements in the Royal Air Force for strategic and tactical aeromedical evacuation. As examples of the emergency cases that provided the bulk of the more difficult special aeromedical flights, the speaker discussed in detail the transport of patients with spinal injury, renal failure and those suffering from multiple injuries. The speaker then described a number of items of new equipment used in the aeromedical evacuation role; the equipment was made available for subsequent examination by the delegates. Finally, the speaker described tactical aeromedical evacuation techniques in the Royal Air Force. This presentation provided the audience with a resume of the broad aspects of the topic and served as a useful introduction to the papers which followed.

Major Ney of the German Air Force Medical Corps then discussed experiences in the air transport of patients in peace time. He highlighted the growing importance of the use of helicopters as a means of evacuating dangerously ill patients, particularly in view of the ever increasing density of road traffic. The presentation was centred around a study of thirty-five actual missions flown in this role. From an analysis of this material, the author had been able to draw useful conclusions concerning the design and layout of the helicopter, and the desirable staff and medical equipment requirements necessary to ensure greater efficiency, safety and speed with maximum in-flight medical care.

The next paper, by Captain Bosee, late of the United States Navy, and James F. Parker Jr., dealt with the aeromedical problems associated with the rescue of downed airmen. The study had been undertaken in an attempt to review specific aeromedical problems arising under combat conditions, and to assess in particular the need for new or improved rescue equipment and techniques. A series of 42 rescues in South East Asia had been studied in order to assess the range of injuries sustained by aircrew personnel under combat conditions. From the results, the need for certain classes of medical support equipment in rescue vehicles was shown, and the specific training requirements for helicopter rescue crewmen described.

The session continued under the Chairmanship of Colonel B. deFine Olivarius of the Royal Danish Air Force. Major Murphy, USAF, described some recent advances and new concepts in the evacuation of patients by air in cargo type aircraft. New equipment had been developed to facilitate the reconfiguration of a cargo type aircraft into an air evacuation role in less than one hour. This permitted the evacuation of casualties by the same aircraft that delivered supplies to forward area airheads. The next paper by Lieutenant Colonel McIver, USAF, MC, discussed the medical considerations affecting early air evacuation of the seriously ill patient. Particular consideration was given to the definition and recognition of the stabilised patient, as well as to the relative and absolute contraindications to patient movement under 'normal' circumstances. In those cases

where unstable patients had to be moved, attention was focused on minimising morbidity and mortality.

The next paper, from the Medical Systems Division of the USAF School of Aerospace Medicine, was presented on behalf of the authors by Lieutenant Colonel Warren, USAF, MC. This described a broad research programme designed to update various aspects of patient care in aeromedical evacuation. The first part of the programme consisted of modernisation of the current inflight medical care system, emphasising various improvements in the accommodation for the patients, diagnostic and therapeutic equipment, and in handling procedures. The team had also considered improvements that would lend themselves to long-term development.

In the last paper in this session, Captain Perry of the Royal Army Medical Corps described a lightweight plastic patient litter based on a suggestion made at the Helicopter Symposium held in Paris last year. It has been designed to meet the requirement for an inexpensive lightweight robust litter, capable of permitting the passage of x-rays, and able to fulfill many roles. The new litter was also buoyant and smaller than the conventional model. This interesting development was still in the prototype stage, and the concept had been presented for consideration by the various authorities concerned with the development of aeromedical equipment.

This was a most interesting and productive session that provided a comprehensive survey of the rapid advances in the techniques of strategic and tactical aeromedical evacuation in the military sphere. It also drew attention to the advantages of aeromedical evacuation in civil emergencies, where road access was slow or limited due to weather or traffic density. This particular requirement tended to centre around the helicopter, which, although offering many advantages, was still relatively expensive to operate, tended to have a small cabin and was somewhat restricted in its all-weather and night flying capabilities. There was considerable interest in the field of aeromedical evacuation and it was clear that much valuable work had been done recently in this sphere. The continued development of airborne techniques and special equipment to permit the maximum usage of whatever aircraft might be available would undoubtedly pay greater and greater dividends in saving lives and reducing the hazard to patients who were remote from expert treatment.

At this juncture, Dr. Karl Houghton, USA, gave a most interesting and informative presentation, including a film, describing a 60-day manned space flight simulation run with regenerative life support. From the test data, it was concluded that the life support system successfully met the test requirements. The crew selection programme had been both effective and predictive, and neither the medical nor the behavioural studies revealed any significant changes. Similarly, the crew support evaluation, sensitivity training and remote instruction were also successful. This contribution to the session on current space medical problems was received with enthusiasm by the delegates.

After this presentation, the Chairman of the Aerospace Medical Panel formally closed the 25th meeting of the Panel.

Looking back over the programme and taking note of the reception that the presentations received, the meeting can be considered to have been both productive and successful, with a satisfactory balance between basic and applied work. It is also most encouraging to report that the papers at this meeting were primarily orientated to the problems of the NATO Operational Commander. This was achieved without excluding space problems entirely; and rightly so.

The papers by members of the Structures and Materials Panel were most welcome and contributed greatly to the success and balance of the session on body armour. Inter-panel activities are interesting and the cross-fertilisation achieved both widens the horizons of each of the Panels involved and at the same time gives specialist workers a greater sense of perspective. Just as in medicine one meets more and more of the psychophysiological approach to the solution of multistress problems, so the coming together of various scientific disciplines is a healthy sign. The very structure of the AGARD organisation lends itself admirably to this type of approach to research and development.

It is difficult to report on all the discussions that took place outside the formal papers. Some of these are included in this appreciation, but much that was equally interesting has

regretfully had to be omitted. Two papers have been included in this report that were not actually presented on the day, and two papers that were given are not available for publication at this time.

In conclusion, the attendance at this meeting was most encouraging and the atmosphere friendly and enthusiastic. It is often said about conferences that the excellence of the presentations is by no means the only measure of the value and success of the meeting. This meeting was no exception to the rule.

T. G. DOBIE,
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PROGRAMME DEPUTY CHAIRMAN
25TH MEETING ASMP

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25TH MEETING OF THE AEROSPACE MEDICAL PANEL

15TH-17TH OCTOBER 1968, LONDON

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